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REVIEW OF AQUATIC TOXICITY AND ENVIRONMENTAL IMPACT OF ONTARIO SEWAGE TREATMENT PLANT EFFLUENTS

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REVIEW OF AQUATIC TOXICITY AND ENVIRONMENTAL IMPACT OF ONTARIO SEWAGE TREATMENT PLANT EFFLUENTS

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SUMMARY

Environment Canada and the Ontario Ministry of the Environment (MOE) have recognized the need for development of effluent discharge limits for sewage treatment plants (STPs) in support of the goals of MOE's Municipal and Industrial Strategy for Abatement Program (MISA). While provincial water quality objectives can provide the basis of chemical limits, the acute lethality rainbow trout and Daphnia magna tests are the only formal measures of effluent toxicity in the province.

This report reviewed the toxicity data available for treated effluents from STPs located in Ontario and other provinces to determine:

- o whether STPs could be categorized with respect to effluent toxicity according to plant type (i.e., primary, secondary and lagoon) and process performance measured in terms of BOD_5 and ammonia removal; and
- o what categories of plants should be evaluated through field sampling and testing to provide the toxicity database that would allow the development of achievable toxicity limits for each plant category.

Review of toxicity and process data for plants indicated that:

- o Effluent toxicity data for plants with only primary treatment were found to be limited, especially for Ontario. The available Ontario and Western Canada primary STP data indicate primary effluents are generally acutely lethal. Secondary and lagoon treatment plants produce effluents of variable quality. It would seem, therefore, that lethality is not related simply to the type of treatment process involved (i.e., primary, secondary or lagoon), but to conditions specific to each plant as well.
- o Although only four Ontario STPs have been investigated with respect to their effluent effects on receiving waters, all four have demonstrated some degree of fish lethality in the effluent plume. Tests at Western Canadian STPs also showed that, under some conditions, in-stream lethality can occur due to the effluent chlorine disinfection step.
- o Ammonia toxicity has been demonstrated in laboratory tests of STP effluents in Ontario. Chlorine toxicity in effluents has been shown in

continuous-flow tests in the laboratory, as well as in in situ field studies. Conventional static bioassays allow dissipation of total residual chlorine and, therefore, result in an inaccurate reflection of its toxic potency. At some STPs, other toxic components may be involved (i.e, metals, surfactants, organics, etc.).

- The amount of receiving water dilution available for an effluent will determine the downstream area where toxic effects will be observed. Estimated instantaneous dilution factors for several Ontario STPs suggest that there are undoubtedly some plants which will generate substantial toxic impact zones. The physical and chemical characteristics of each receiving water body may also affect the toxicity of various components of the effluent, as well as their persistence.
- Biological tests of treatment plant effluents can reliably predict whether the receiving waters are affected by the discharge. Acute and chronic tests with a variety of representative receiving water species provide a good estimation of field effects.
- Process operating efficiency, as measured in terms of total NH_3-N seems to be a more reliable determinant of effluent lethality than the type or amount of industrial input. However, the data available for this review on industrial inputs were limited.
- Both high total ammonia-N concentrations and poor BOD_5 removal efficiency may be responsible for the toxic effluents from primary plants.
- In secondary plants, in spite of high BOD_5 removal efficiencies (e.g., greater than 80%), effluents were frequently toxic if the total ammonia-N concentration exceeded 10 mg/L. This was very often the case during winter operation, with high total ammonia-N levels apparently resulting from reduced nitrification at lower wastewater temperatures.
- Effluent toxicity associated with lagoon operation was most frequently associated with both high total ammonia-N concentrations and poor BOD_5 removal efficiency, rather than with high total ammonia-N concentrations alone. As with the primary effluents, the toxicity may be due to ammonia or other toxicants such as hydrogen sulphide.
- The chlorination of effluents may also result in sublethal impact on aquatic biota in receiving environments.
- Information on sublethal or chronic toxicity of treated STPs' effluents was limited in the literature.

This report recommends that an intensive evaluation of STP effluent toxicity be completed on selected plants from each identified category that are representative of good operational performance (e.g., total ammonia is less than 10 mg/L, BOD reduction greater than 80%, and hydraulic loading does not exceed design capacity). The following items should be incorporated in the effluent evaluation study:

- in future municipal effluent toxicity testing efforts, an attempt should be made to verify the apparent relationship between effluent ammonia levels and acute toxicity so a more precise estimate of the effluent toxicity threshold can be identified and expressed in terms of un-ionized ammonia (NH_3), which is the toxic form of the total ammonia measurement.
- sublethal or chronic toxicty tests of effluent quality should be included in the field program;
- toxic effluents should be further analyzed to identify toxic agents; and
- field assessments should be completed to quantify the TRC impact on the receiving environment and calibrate results with laboratory toxicity tests.

This evaluative approach to describing the effluent quality of plants which typically demonstrate good operational performance will identify achievable effluent limits expressed in terms of acute and chronic toxicity.

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1.0 INTRODUCTION

1.1 Preamble

The Ontario Ministry of the Environment has recently implemented the Municipal and Industrial Strategy for Abatement Program (MISA) in an attempt to control persistent toxics discharged in industrial and municipal plant effluents to receiving waters in the province. Two major approaches are being used to set effluent limits in the MISA program: the Best Available Technology-based approach and the site-specific water quality control approach. The water quality approach will be determined by comparison with compliance to Provincial Water Quality Objectives, actual site-specific evaluation of receiving environment quality, effluent chronic toxicity results extrapolated to ambient limits, or a combination of these processes. An economical and efficient means of estimating environmental impact is to complete a toxicity test on the effluent discharged. The toxicity testing represents a first approximation of what biological impact might result when the effluent is discharged to the receiving water. Once a sufficiently broad profile of effluent toxicity has been established, then minimum toxicity performance limits could be set for final effluents.

1.2 Study Objectives

This study reviews the toxicity of municipal sewage treatment plant effluents in Ontario and other provinces. All Ontario STPs currently in operation can be categorized according to their process and performance characteristics. This review is intended to assist in the prioritization of Ontario STPs for the purpose of conducting a limited effluent toxicity field monitoring program during the municipal sector pre-regulatory monitoring period of the MISA program. This will assist in forming the basis for determining appropriate toxicity testing requirements for different categories of plants.

The specific objectives of the study were as follows:

- to conduct a literature search to locate all appropriate literature dealing with STP effluent toxicity and receiving water impacts resulting from STP discharges; particular emphasis was to be placed on Ontario studies, but other North American studies were also to be utilized;

- to compile and tabulate all effluent toxicity data and associated relevant chemical monitoring information to ascertain the importance of specific contaminants to the toxicity of non-chlorinated, chlorinated and dechlorinated final effluents;
- individuals knowledgeable with Ontario municipal effluents and treatment plant operations were to be contacted to secure relevant unpublished data and information on individual plant operating efficiency and frequency of wastewater treatment system upset events;
- to generate maps detailing the location, treatment system type and water body receiving STP effluent for all Ontario plants;
- to determine the effects of particular chemical agents, industrial waste contribution and seasonal changes in treatment system performance;
- to categorize all Ontario STPs with respect to the proportion of industrial versus domestic waste inflow; and
- to discuss the significance of effluent chlorine residual in terms of effluent toxicity testing; and
- to discuss the benefits and limitations of various effluent dechlorination techniques available for residual chlorine removal prior to toxicity testing.

1.3 Report Organization

This report has been organized to follow a logical progression. Initially, all available toxicity data from tests of STP effluents in Ontario and the rest of Canada were examined (Sections 2.0 and 3.0). The toxicity was then analyzed in relation to the physical and chemical characteristics of the effluent (Section 4.0). In this manner, the toxic agents which were felt to be the most important in laboratory effluent toxicity studies reviewed were identified. STP effluent toxicity was then evaluated in terms of environmental effects, such as the season and the characteristics of the receiving water (Section 5.0). In the next step, the characteristics of the waste treatment processes were related to the toxicity results (Section 6.0). The operation of various types of Ontario STP effluent treatment systems and the specific conditions leading to the production/release of the identified toxic agents were discussed. It was then possible to categorize all Ontario STPs with respect to those process characteristics and to identify selected plants that could be tested to describe the best achievable performance (with respect to toxicity) expected of each category (treatment system type).

1.4 Measurement of Effluent Toxicity

The term "toxicity" refers to a wide range of biological responses, all of which represent impairment to the normal functioning of an organism or a community. A toxic response in organisms results from a critical exposure to chemicals, compounds or a change in the physical environment. Typically, industrial and municipal effluent discharges contain a number of contaminants, some of which may exceed their known individual toxic level. However, in a complex effluent mixture, the presence of one contaminant can increase or decrease the toxic effect of another contaminant. The interactions among toxicants will be as numerous as the number and combinations of contaminants in a mixed effluent. Therefore, knowing toxicant concentrations and the period of exposure alone is insufficient to precisely predict final effluent toxicity, since the interactions of toxicants can rarely be quantified. On the other hand, exposing biological organisms to complex effluents takes the guessing out of estimating the toxicity of individual compounds the the interaction with other contaminants.

The simplest way to estimate the toxicity of a liquid effluent in a receiving water is to conduct a laboratory toxicity test using standard test organisms and test protocol. The organisms used are representative of those expected to inhabit the receiving water, e.g., fish, invertebrates and algae. The organism responses monitored to determine toxicity include lethality, impaired growth, impaired reproduction or impaired physiological function. The laboratory test is more economical than similar tests that might alternatively be conducted in the actual receiving water using indigenous organisms.

The most frequent first-evaluation of an effluent is the determination of the LC50, a measure of acute lethality. This is the concentration which causes lethality in 50% of the exposed test organisms. Usually, a 96-hour test is used to determine the "acute" or short-term effects on fish, while a slightly shorter period, typically 48 hours, is used for smaller organisms (e.g., Daphnia). "Chronic" tests are used to measure long-term effects on organisms, and show effects on growth, reproduction, behaviour, etc. and, while not directly lethal to individuals, would contribute to the demise or lack of competitive vigour of a community, and therefore result in ecosystem impairment. When responses other than lethality are measured, the effluent exposure concentration which results in an impairment to 50% of the test organisms is called the EC50 (concentration which will affect 50% of exposed organisms).

Acute and chronic toxicity is measured by placing a suitable number of test organisms in effluent diluted with dechlorinated tap or actual receiving water. The dilutions are made following a logarithmic scale. The percentage of organisms which have been affected by each effluent dilution is then plotted on a probit or probability scale against the percent concentration on a logarithmic scale. A line of best fit is calculated and the 50% effect concentration (including 95% confidence intervals) is determined. The results of effluent toxicity tests are always expressed as a percent volume of effluent (i.e., % v/v).

1.5 Application of Effluent Toxicity Tests

Acute and chronic toxicity tests are used to quantify the combined toxicity of individual effluent contaminants, and to estimate the overall effect of this effluent on the receiving water ecosystem. Toxicity test results expressed as percent effluent can be used, together with hydraulic characteristics of the receiving water, to estimate the area of receiving water or distance downstream of a discharge pipe that may be toxic to aquatic life.

1.6 Ontario Sewage Treatment Plant Types

In this study, municipal sewage treatment plants in Ontario have been classified as:

- primary plants,
- secondary plants, or
- lagoons.

Primary treatment plants are principally designed to reduce particulate matter in raw wastewater without substantially reducing the soluble organic matter measured as biochemical oxygen demand (BOD_5). Treatment is accomplished by clarification assisted by chemical flocculation. Ammonia-nitrogen concentrations in the wastewater are not reduced by this process. The primary treatment group in this study includes both mechanical primary treatment facilities and communal septic tanks.

Secondary treatment facilities are those which use biological treatment processes to remove soluble organic matter. Air is added by mechanical equipment, such as diffuser mixers, to accelerate the biodegradation rate. BOD_5 and suspended solids are reduced to

low concentrations (e.g., 20 mg/L or less each) by secondary treatment. Ammonia-nitrogen may be reduced to low concentrations (e.g., 5 mg/L or less), depending on process design operation, sewage temperature and industrial inputs in the raw wastewater received by the plant. Treatment facilities included in the secondary plant category include conventional activated sludge, extended aeration, high rate activated sludge, contact stabilization, oxidation ditches and trickling filters. In Ontario, most sewage treatment facilities are not designed to remove ammonia nitrogen.

Lagoons (wastewater stabilization ponds) are non-mechanical treatment facilities in which the wastewater is typically purified by biological activity at naturally-occurring rates. The air required for the biological activity to occur is supplied through oxygen transfer between the atmosphere and liquid sewage surface. An exception to this is the aerated lagoon or aerated cell plus lagoon, in which air is mechanically transferred to the wastewater in a lagoon or cell at a much lower rate than secondary plants. The hydraulic retention time of the lagoons is typically 10 to 30 days to allow for carbon oxidation to occur naturally (as compared with mechanical secondary treatment plants where the total hydraulic retention time in the plant may be 10 to 12 hours). Although BOD removal efficiency may be as high in lagoons as in secondary treatment facilities, suspended solids removal efficiency is often not as high due to growth of algae which discharge with the lagoon effluent. Ammonia-nitrogen may be partly oxidized to nitrate or remain unchanged in the lagoon, depending on temperature and dissolved oxygen concentration. Hydrogen sulphide is a toxic contaminant which is present in lagoon treatment system effluents.

Included in this group of treatment facilities are aerated lagoons or aerated cells plus lagoons, conventional lagoons with annual, seasonal or continuous discharge, lagoons with spray irrigation and exfiltration lagoons.

This categorization of all municipally- and MOE-operated treatment plants will result in process groups with the following number of elements:

- primary: 42 plants
- secondary: 211 plants
- lagoons: 148 plants

for a total province-wide of 401 treatment facilities. Two lagoon treatment plants, Stoney Creek (Bartletts) and Kapuskasing (Val Albert), which were included in the MOE (1985) "Report on Discharges from Municipal Wastewater Treatment Facilities in Ontario", were not evaluated as these plants ceased operations in April and January 1985, respectively.

2.0 HISTORICAL LABORATORY TOXICITY TESTS OF CANADIAN STPs

This section presents all the available historical data concerning the toxicity of non-chlorinated Ontario STP effluents. Discussion of these results with respect to particular effluent characteristics and plant processes is dealt within Sections 4.0 to 7.0.

Table 2.1 lists the names and agency affiliations of individuals contacted during the initial search for Ontario STP toxicity information. Although quite a number of STP effluents in Ontario have been tested (33 plants in total), the data for each plant were often old and scant (Appendix A, Table A1). The effluent of most of these STPs was evaluated for toxicity on a limited number of occasions. Physical/chemical properties of the effluent were often not measured or reported, many of the studies were conducted over a decade ago and may not reflect current conditions, and frequently only a whole effluent (100% concentration) test was conducted which did not permit the calculation of an LC50. Other Canadian data (Appendix A, Table A2) have, therefore, been incorporated into this report to substantiate or confirm observations made based on Ontario toxicity studies. In the comparison of Ontario and other Canadian STP toxicity data, it was assumed that the seasonal patterns (e.g., cold winters) and the treatment technology would be similar across Canada.

Data reviewed pertaining to chlorinated effluents are presented later in Section 4.2, where toxicity of total residual chlorine is discussed.

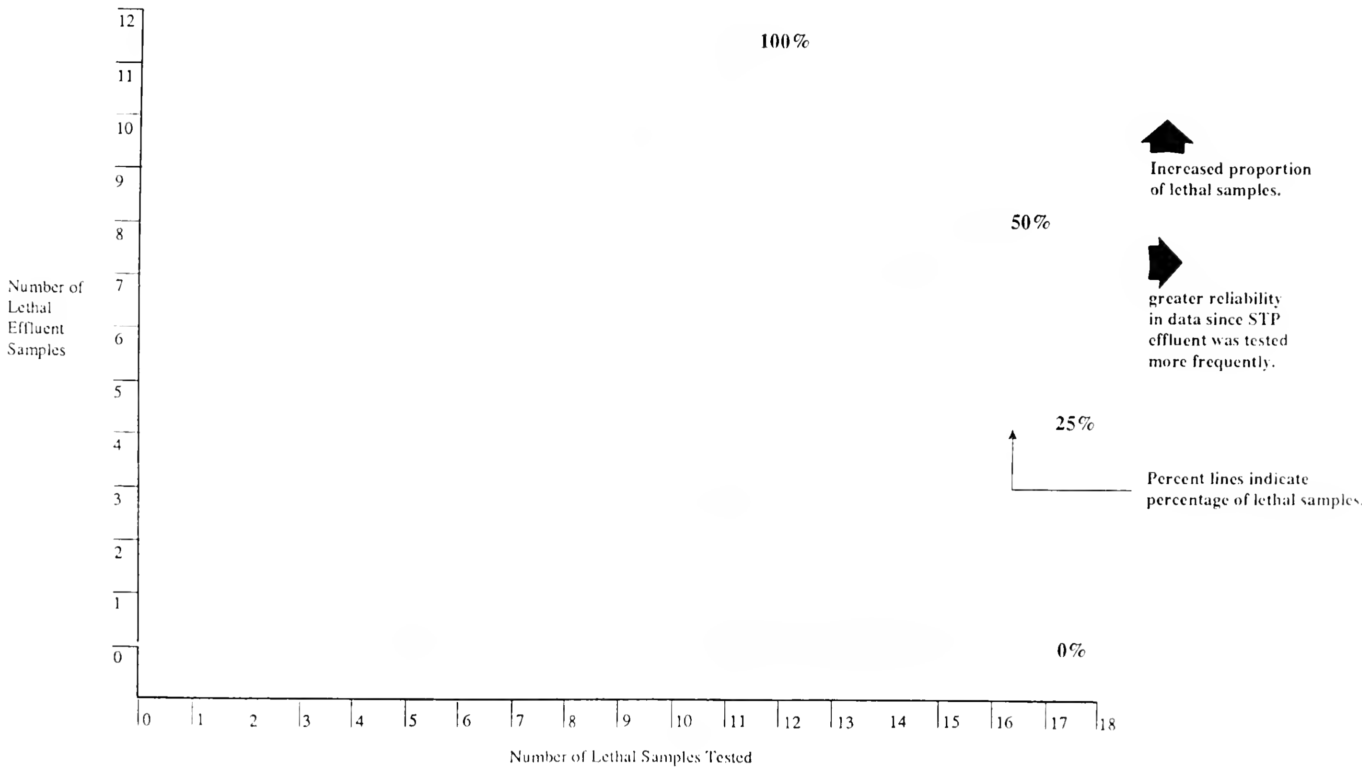
Due to the lack of toxicity data calculated as LC50's in the studies reviewed, the effluent data were judged to be toxic if the sample caused 50% or greater mortality to the exposed test organisms. All effluent toxicity results available are graphically presented for each STP following the format depicted in Figure 2.1, which shows the percent samples tested that were acutely toxic. Results for different sampling periods and/or different laboratories are reported as separate sets of data (i.e., proportion of lethal samples in tests conducted by the MOE in a specific time period are plotted separately from CANVIRO/BEAK data for the Galt and Waterloo STPs).

Rainbow trout (Salmo gairdneri) were the most frequently utilized test species, but data from other species were included when available, and are indicated on the respective figures. While the degree of lethality varied between species. Table 2.2 depicts that

TABLE 2.1: INDIVIDUALS AND AGENCIES CONTACTED DURING SEARCH FOR INFORMATION ON ONTARIO STP EFFLUENT TOXICITY

Name	Affiliation	Information Received
Vic Chin	MOE - Toronto	-
Fritz Engler	MOE - Toronto	-
Ken Flood	MOE - Toronto	Stratford, Tillsonburg
Yousry Hamdy	MOE - Toronto	-
John Kinkead	MOE - Toronto	-
Henry Kronis	MOE - Toronto	-
Wes Hammers	MOE - Toronto	-
John Lee	MOE - Toronto	-
Gary Westlake	MOE - Toronto	-
Arch McClarty	MOE - Hamilton	-
John Vogt	MOE - Hamilton	-
Stew Thornly	MOE - London	Greenway, Walkerton
Jack Pruner	MOE - Kingston	-
Jerry Myslik	MOE - Sudbury	-
Jake Vander Waal	MOE - ThunderBay	-
Brenda Axon	Halton Region C.A.	Milton
Geza Gaspardy	Credit Valley C.A.	-
Brian Hindley	Metro Toronto Region C.A.	-
-	Hamilton C.A.	-
-	Long Point Region C.A.	-
-	Niagara Peninsula C.A.	-
-	South Lake Simcoe C.A.	-
-	Upper Thames C.A.	-
Vic Cairns	D.F.O. - Burlington	through R. Scroggins
Leonard Yust	Regional Municipality of Halton	-

FIGURE 2.1
Format Used for Presentation of Results
from Canadian STP Effluent Toxicity Tests



actual occurrences of lethality versus non-lethality agreed in more than 85% of the interspecies comparisons. For this reason, and due to the paucity of data, subsequent evaluation of the toxic components in the STP effluents (Section 4.0) included chemical data from both rainbow trout and daphnid toxicity tests.

2.1 Ontario Acute Toxicity Test Data Assessed Against Treatment System Type

The following results of the toxicity tests are presented according to the three basic process types identified, primary, secondary, and lagoon systems. All the toxicity data are taken from Appendix A, Table A1, and, where sufficient data were available, are presented according to the format described in Figure 2.1. Discussion of effluent constituents and treatment plant process characteristics which relate to the toxic potency of the effluents has been deferred to Sections 4.0 and 7.0, respectively.

2.1.1 Primary Treatment Systems

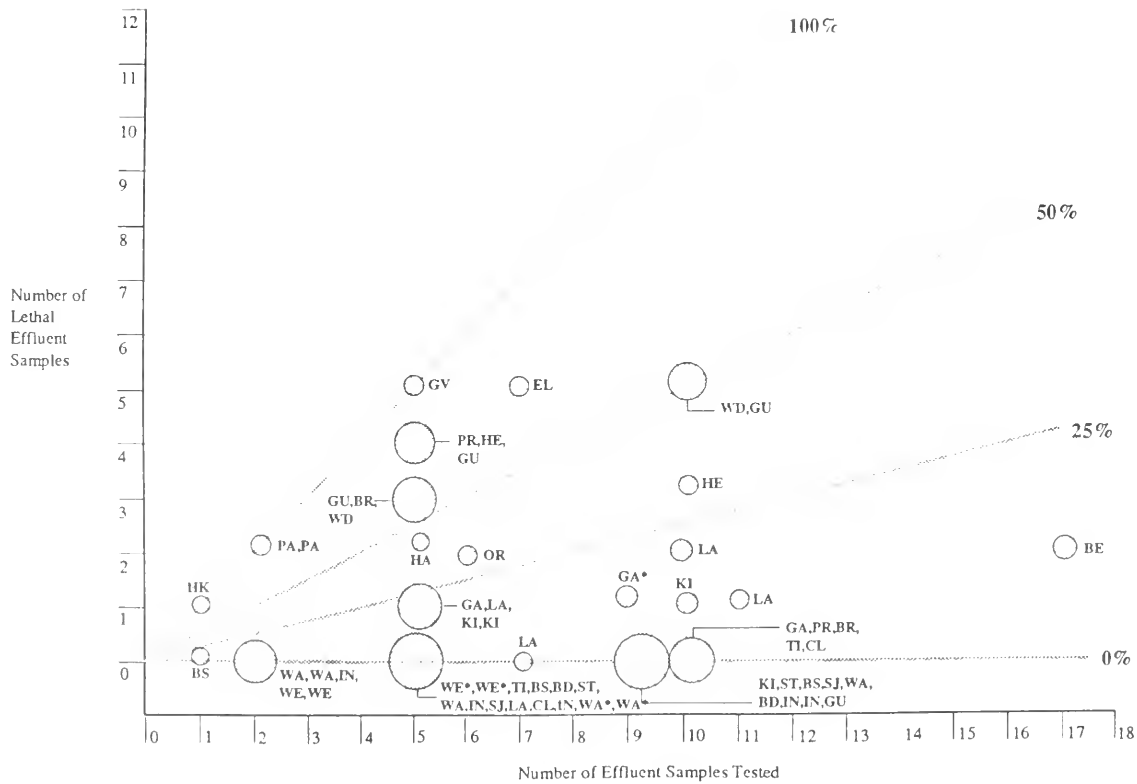
Forty-three (approximately 10%) of Ontario's sewage treatment plants employ only primary treatment. However, only two of these plants have been evaluated for effluent toxicity. One non-chlorinated effluent sample from the Cornwall STP resulted in 96-h LC50 of 83% effluent while the chlorinated effluent sample was not acutely lethal (MOE, 1983). A final effluent sample from Iroquois resulted in an LC50 of 38% (MOE, 1983).

Although toxicity data from primary plants are very limited, Metikosh et al. (1980) tested the primary effluents from 21 secondary plants in Ontario, and found that the primary effluents from each of these plants was acutely lethal to rainbow trout.

2.1.2 Secondary Treatment Systems

The relative toxicity of all secondary sewage treatment plants in Ontario is presented in Figure 2.2. A high proportion of secondary effluent samples tested were non-lethal (based on the arbitrary criteria that samples showing less than 50% mortality were considered non-toxic). However, results from Guelph and Preston STPs show that toxicity can vary on different occasions.

FIGURE 2.2
Toxicity of Non-Chlorinated Effluents from Secondary Sewage Treatment Plants in Ontario to Rainbow Trout (Unmarked) and Daphnia magna (*)



Code	STP
BD	Burlington, Drury Lane
BE	Brampton, Experimental
BR	Brantford
BS	Burlington Skyway
CL	Clarkson
EL	Elmira
GA	Galt
GU	Guelph
GV	Grand Valley
HA	Hamilton
HE	Hespeler
HK	Hawksbury
IN	Ingersoll
KI	Kitchener
LA	Lakeview
OR	Orangeville
PA	Paris
PR	Preston
ST	Stratford
SJ	St. Jacobs
TI	Tilsonburg
WA	Waterloo
WD	Waterdown
WE	Welland

TABLE 2.2: RESULTS OF INTER-SPECIES COMPARISONS OF STP EFFLUENT TOXICITY SHOWING GOOD CORRELATION BETWEEN SPECIES IN DEMONSTRATING LETHALITY OR NON-LETHALITY OF AN EFFLUENT

Reference	Species LC50					
	Salmo gairdneri	*Daphnia magna*	*Hyallela azteca*	*Daphnia pulex*	*Occonectes virilis*	*Ictalurus melas*
Canviro, report in progress	N.L.	N.L.				
	N.L.	N.L.				
	N.L.	N.L.				
	N.L.	N.L.				
	N.L.	N.L.				
	N.L.	N.L.				
	N.L.	N.L.				
	N.L.	N.L.				
	26	39				
	84	38				
	N.L.	71				
	N.L.	N.L.				
	N.L.	N.L.				
	N.L.	N.L.				
	N.L.	N.L.				
	N.L.	N.L.				
	N.L.	N.L.				
	N.L.	N.L.				
	N.L.	21				
	N.L.	53				
	N.L.	N.L.				
	N.L.	N.L.				
Clarke *et al.* (1977)	L 52.2		53.5	L 31.6	69.6	
	L 52.2		16.7			
	L 15.3					L 15.3

L. = less than.
N.L. = not lethal.

2.1.3 Lagoon Treatment Systems

Metikosh et al. (1980) evaluated the toxicity of effluents from Listowel , Markdale, Mitchell, Tavistock, and Wingham lagoons. The MOE (1983) also tested the effluents from Alexandria and Lindsay. The results presented in Figure 2.3 show that, on occasion, lagoon treatment systems also produce lethal effluents.

2.2 Ontario Chronic Toxicity Test Data

Chronic effluent toxicity tests measure the longer-term effects of an effluent on an organism compared to the short-term (48- to 96-hour) acute tests. Chronic tests (i.e., greater than 96 hours) may also produce a lethal response at higher exposure concentrations while measuring a sublethal effect (e.g., EC50, NOEC, LOEC, MATC) at lower concentrations. The Ceriodaphnia reproduction test, for example, measures the production of young, and the endpoints are the highest no observable effect concentration (NOEC) and the lowest observable effect concentration (LOEC). The point of reference used to compare test results among samples is the chronic value concentration which is the geometric mean of the NOEL and LOEC.

Galt is the only Ontario STP which has been evaluated for chronic effluent toxicity. Table 2.3 shows that a chronic value concentration of 39 to 71% effluent caused a significant decrease in the number of young Ceriodaphnia produced in a reproduction test. A chronic test of lethality was also conducted, and resulted in three seven-day LC50's ranging from 46 to 88% and one non-lethal sample.

2.3 Toxicity Categorization of Ontario STPs

Based on the proportion of lethal effluent samples determined for each Ontario STP, each plant was placed into one of three categories:

1. non-lethal,
2. intermittently lethal, and
3. lethal.

FIGURE 2.3
Toxicity of Non- Chlorinated Effluents from Lagoon Sewage Treatment Plants in Ontario to Rainbow Trout

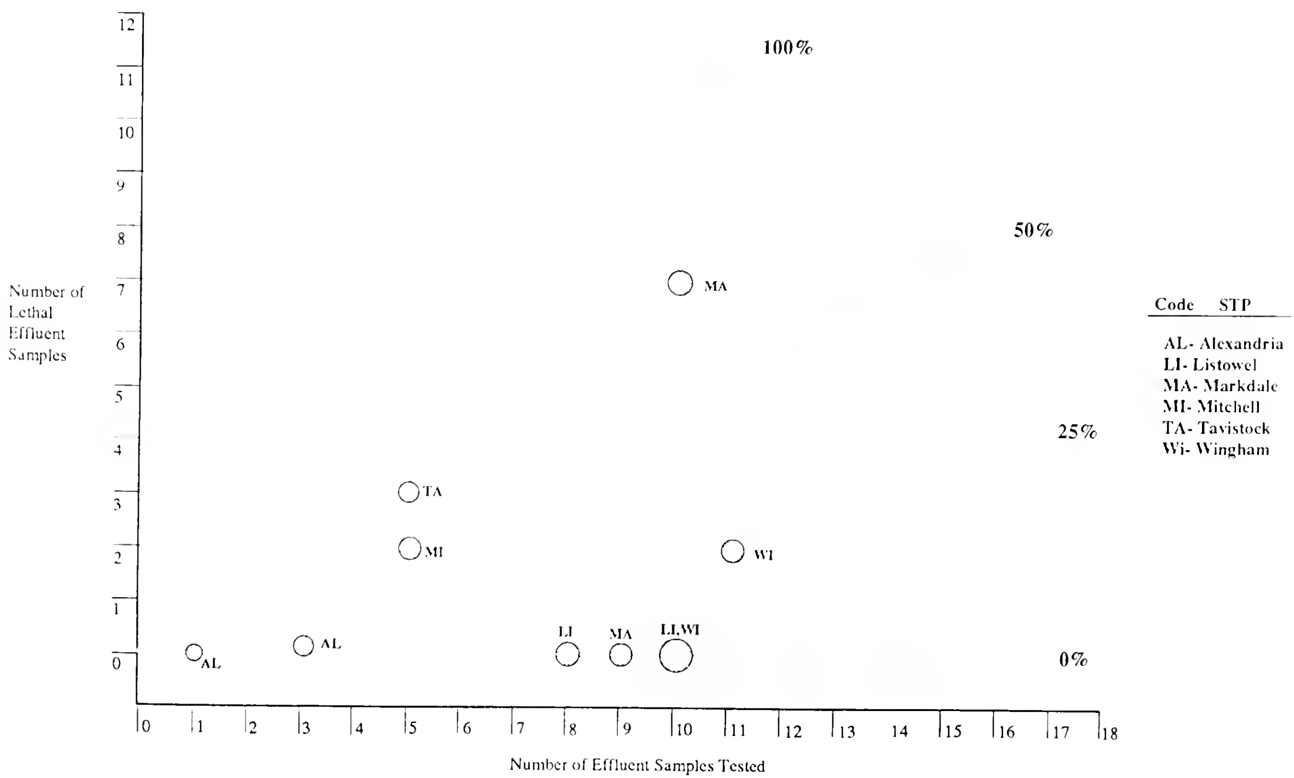


TABLE 2.3: LETHAL AND SUBLETHAL CHRONIC TOXICITY OF GALT STP EFFLUENT TO CERIODAPHNIA

Sampled (d.m.y.)	Effluent Type	Test Type	Response*	Effluent Concentration (%)
05.10.86	Non-chlorinated	Static, 7-day	LC50	88
06.10.86		Lethal Test		46
07.10.86	Chlorinated			GT 100
08.10.86				76
05.10.86	Non-chlorinated	Static, 7-day	Chronic	71
06.10.86		Reproductive	Value	39
07.10.86	Chlorinated	Impairment Test**		71
08.10.86				71

* LC50 - Concentration lethal to 50% of organisms.

** Measures significant decreases in the number of young produced.

GT - greater than.

Chronic Value - geometric value of the NOEL and LOEC.

The non-lethal category included all plants which never produced an effluent sample causing acute lethality (Table 2.4). Those plants deemed intermittently lethal were those which caused acute lethality in at least one sample, but never in greater than 50% of the samples tested within a set (Table 2.5). The remaining group of plants with lethal effluents produced at least one batch of samples where 50% or more of the samples were lethal (Table 2.6).

2.4 Effluent Toxicity Data from Other Canadian STPs

The results of toxicity tests conducted on non-chlorinated effluents from STPs in western Canada are presented in Appendix A (Table A2). As in Section 2.1 (Ontario data), the results have been summarized in figures demonstrating the proportion of samples found lethal. The possible constituents and factors affecting toxicity of Canadian STP effluents are discussed in Sections 4.0 and 5.0. No information was available for STPs in provinces east of Ontario.

2.4.1 Primary Treatment Plants

The final effluents of primary STPs in Saskatchewan and British Columbia caused acute lethality to rainbow trout in all samples, with LC50's in the range of 17 to 86.5%. Figure 2.4 represents the proportion of acutely toxic samples out of each group of samples analyzed from Canadian STPs utilizing primary treatment only. The high proportion of toxic samples supports the postulation from Ontario data that primary treatment does little to reduce wastewater toxicity.

2.4.2 Secondary Treatment Plants

Many of the samples tested from secondary STPs in Western Canada caused acute lethality to organisms (Figure 2.5). Similar to Ontario results, the variation in lethality between plants indicates that lethality at secondary STPs is not likely related to the process type, but to more specific conditions of each plant or the quality of raw influent. As mentioned above, Sections 4.0 to 7.0 discuss the factors affecting effluent lethality.

TABLE 2.4: ONTARIO STPs WHICH PRODUCE NON LETHAL EFFLUENTS AS JUDGED BY LABORATORY TESTS OF NONCHLORINATED FINAL EFFLUENTS*

STP Location	Study Date (m/y)	No. of Samples Tested	No. of Lethal Samples	Reference
Alexandria	08.77	1	0	MOE (1983)
	06.81	3	0	
Burlington, Drury Lane	08-10.77	9	0	Metikosh et al. (1980)
	01-02.78	5	0	
Burlington, Skyway	10.76	1	0	MOE (1983)
	08-10.77	9	0	Metikosh et al. (1980)
	01-02.78	5	0	
Clarkson	08-10.77	10	0	Metikosh et al. (1980)
	01-02.78	5	0	
Ingersoll (I)	08-10.77	9	0	Metikosh et al. (1980)
	01-02.78	5	0	
Ingersoll (II)	08-10.77	9	0	Metikosh et al. (1980)
	01-02.78	5	0	
Ingersoll**	12.79	1	0	MOE (1983)
	04.80	1	0	
Listowel	12.77-04.78	9	0	Metikosh et al. (1980)
St. Jacobs	08-10.77	9	0	Metikosh et al. (1980)
	01-02.78	5	0	
Stratford	08-10.77	9	0	Metikosh et al. (1980)
	01-02.78	5	0	
Tillsonburg***	08-10.77	10	0	Metikosh et al. (1980)
	01-02.78	5	0	
Waterloo	08-10.77	9	0	Metikosh et al. (1980)
	01-02.78	5	0	
	07.86	7	0	BEAK (1986b)
	07.86	7	0	
	07.86	3	0	MOE (1986)
Welland	08.86	7	0	BEAK (1986c)
	08.86	7	0	

* This category includes all STPs which have not produced any acutely lethal effluents during any sampling period.

** Addition of chlorine resulted in lethality.

*** In situ cage study has shown that chlorine disinfection can cause acute lethality in fish downstream (Flood et al., 1984b).

TABLE 2.5: ONTARIO STPs WHICH PRODUCE INTERMITTENTLY LETHAL EFFLUENTS AS JUDGED BY LABORATORY TESTS OF NONCHLORINATED FINAL EFFLUENTS*

STP Location	Study Date	No. of Samples Tested	No. of Lethal Samples	Reference
Brampton**	02-11.75	17	2	Cairns and Conn (1977)
Galt	08-10.77	10	0	Metikosh _et al._ (1980)
	01-02.78	5	1	
	10.86	9	1	BEAK (1986a)
	10.86	8	0	
Hamilton	08-10.77	8	0	Metikosh _et al._ (1980)
	01-02.78	5	2	
Kitchener (I)	08-10.77	9	0	Metikosh _et al._ (1980)
	01-02.78	5	1	
Kitchener (II)	08-10.77	10	1	Metikosh _et al._ (1980)
	01-02.78	5	1	
Lakeview (I)	08-10.77	11	1	Metikosh _et al._ (1980)
	01-02.78	5	0	
Lakeview (II)	08-10.77	7	0	Metikosh _et al._ (1980)
	01-02.78	5	0	
Lakeview (III)	08-10.77	10	2	Metikosh _et al._ (1980)
	01-02.78	5	1	
Mitchell	12.77-05.78	5	2	Metikosh _et al._ (1980)
Orangeville	08-10.77	9	0	Metikosh _et al._ (1980)
	01-02.78	6	2	
Wingham	12.77-05.78	12	4	Metikosh _et al._ (1980)

* This category includes all STPs which produced less than 50% and greater than 0% acutely lethal samples in any sampling period.

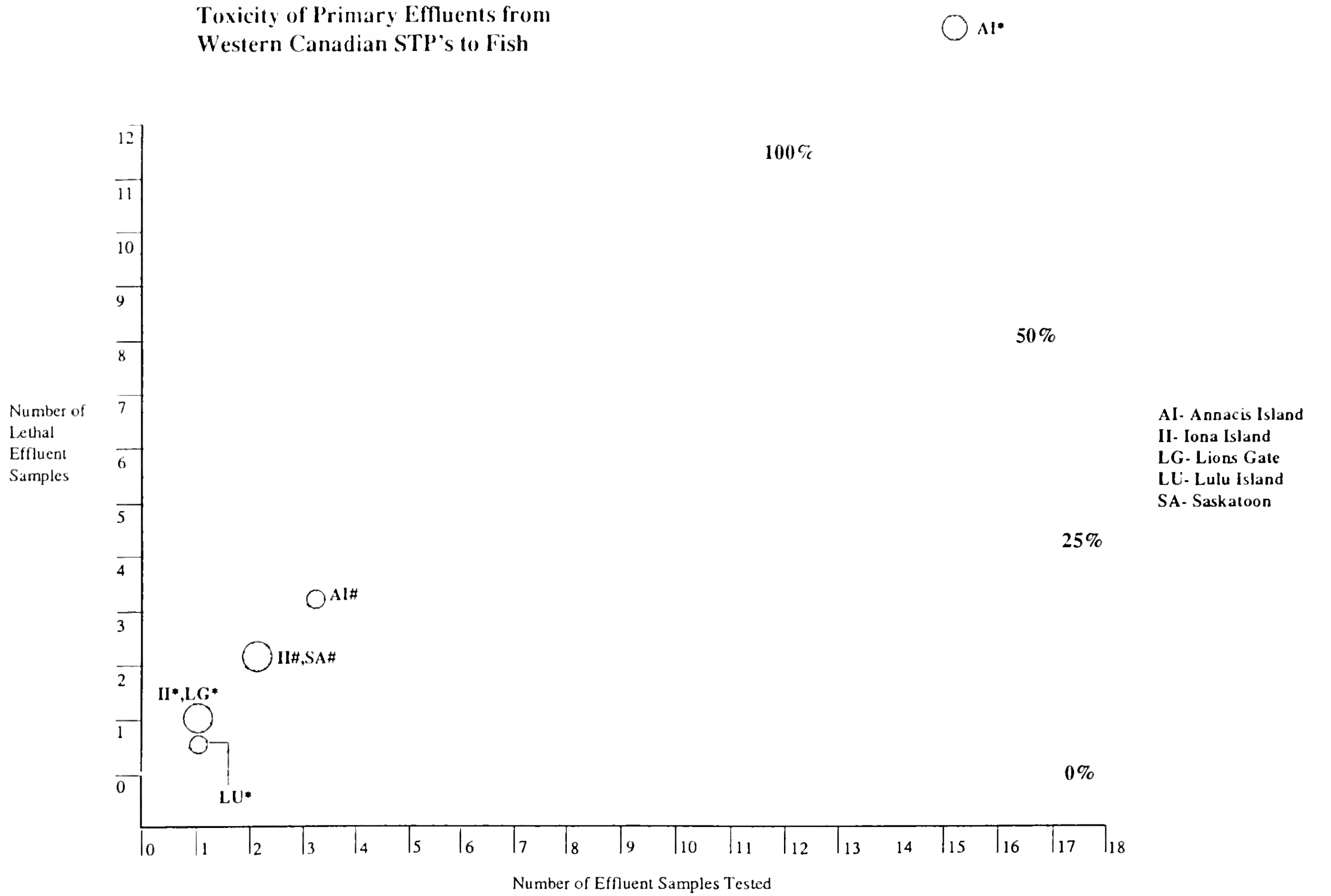
** Addition of chlorine resulted in lethality.

TABLE 2.6: ONTARIO STPs WHICH PRODUCE LETHAL EFFLUENTS AS JUDGED BY LABORATORY TESTS OF NONCHLORINATED EFFLUENTS*

STP Location	Study Date	No. of Samples Tested	No. of Lethal Samples	Reference
Brantford	08-10.77 01-02.78	10 5	0 3	Metikosh *et al.* (1980)
Elmira	09.76-07.82	7	5	MOE (1983)
Grand Valley	08-10.77 01-02.78	8 5	0 5	Metikosh *et al.* (1980)
Guelph (I)	08-10.77 01-02.78	10 5	5 3	Metikosh *et al.* (1980)
Guelph (II)	08-10.77 01-02.78	9 5	0 4	Metikosh *et al.* (1980)
Hespeler	08-10.77 01-02.78	10 5	3 4	Metikosh *et al.* (1980)
Markdale	12.77-05.78	11	7	Metikosh *et al.* (1980)
Paris	11.76-12.77 03.81	2 2	2 2	MOE (1983)
Preston	08-10.77 01-02.78	10 5	0 4	Metikosh *et al.* (1980)
Tavistock	12.77-05.78	5	3	Metikosh *et al.* (1980)
Waterdown	08-10.77 01-02.78	10 5	5 3	Metikosh *et al.* (1980)

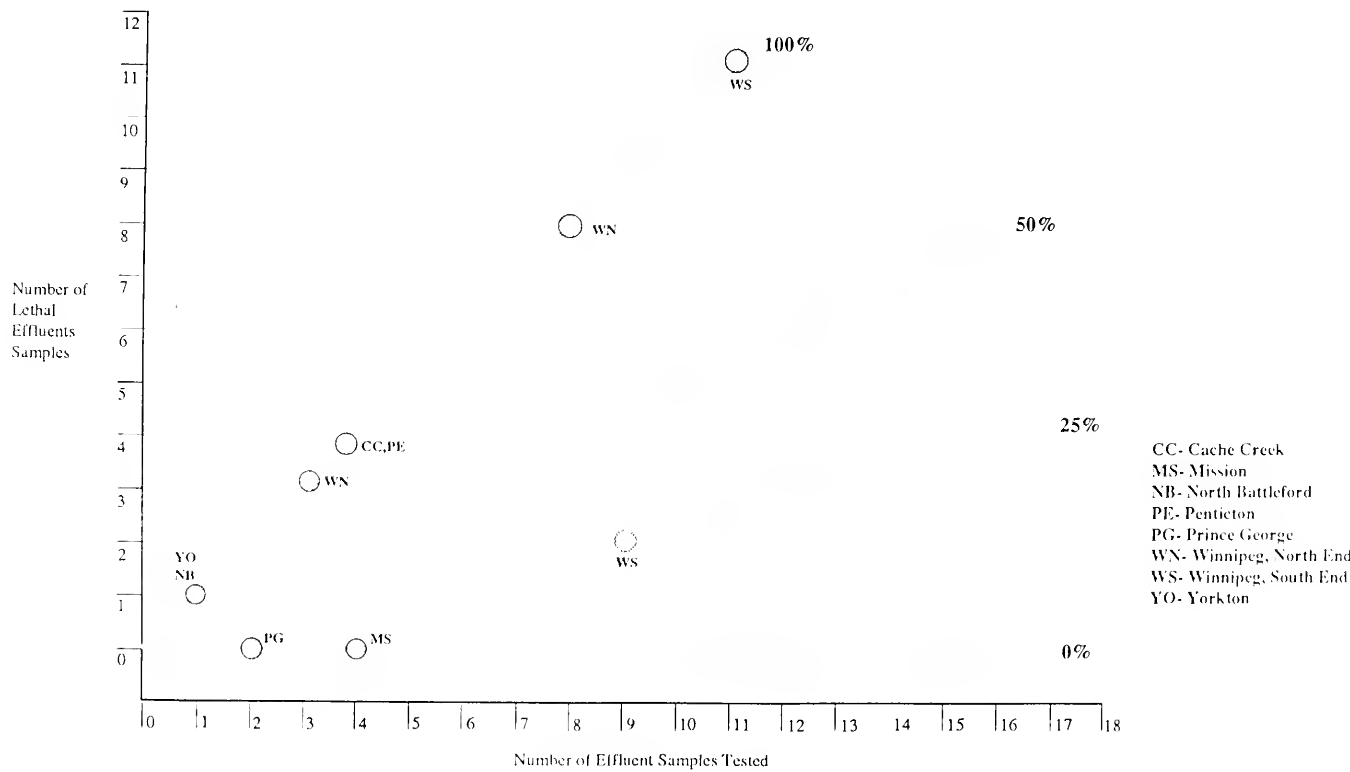
* This category includes all STPs which produce greater or equal to 50% acutely lethal samples in any sampling period.

FIGURE 2.4
Toxicity of Primary Effluents from Western Canadian STP's to Fish



Rainbow Trout (Salmo gairdneri)
* Sockeye Salmon (Oncorhynchus nerka)

FIGURE 2.5
Toxicity of Non-chlorinated Effluents from Secondary and Lagoon Sewage Treatment Plants in Western Canada to Rainbow Trout



2.4.3 Lagoon Treatment Plants

The proportion of lethal effluents taken from lagoon treatment systems in Western Canada is presented in Figure 2.6. As with the secondary treatment plants, the sample populations were generally small.

The study of the Regina Wastewater Stabilization Pond (WSP) was more thorough, but was complicated by chlorination followed by tertiary clarification. Presumably, the added retention time required for lime and alum clarification allowed dissipation of a large proportion of TRC, so these results have been incorporated into the evaluation of non-chlorinated effluent toxicity.

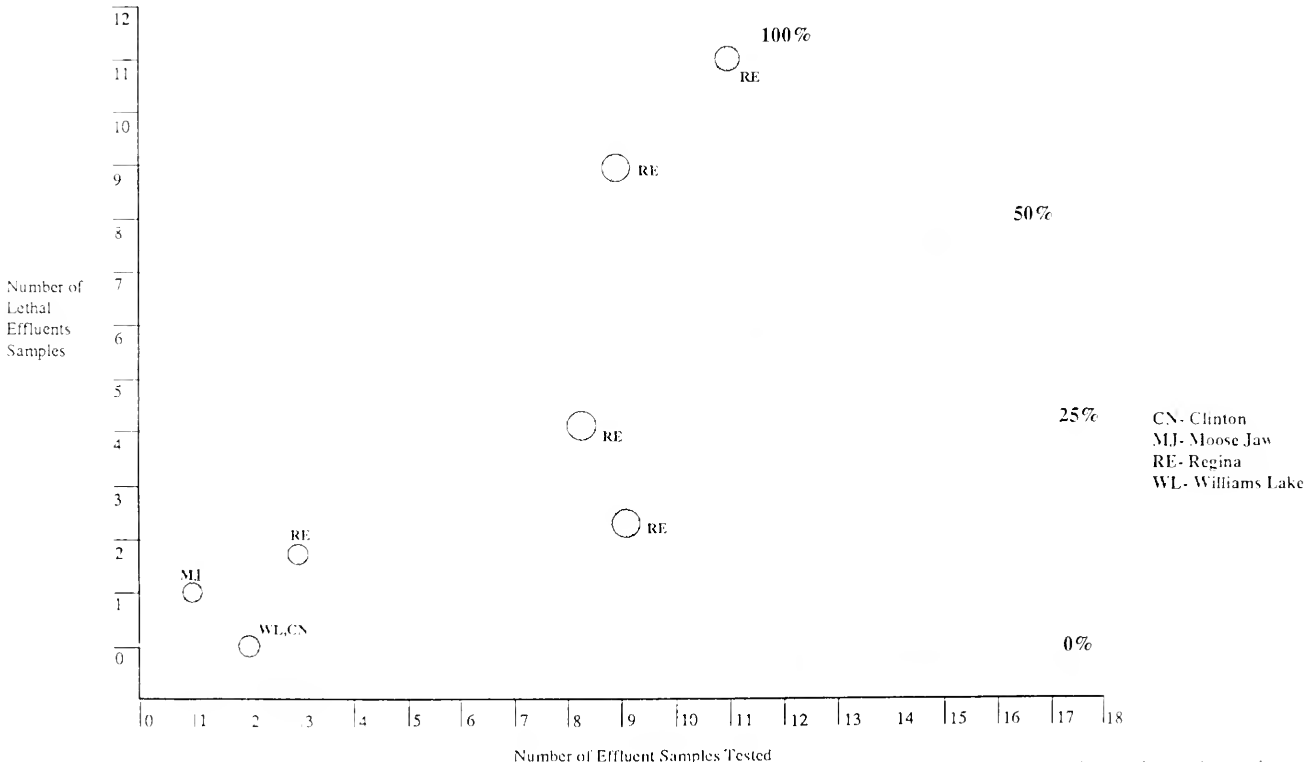
2.5 Summary

The historical data of Ontario STP effluent toxicity indicate that primary plant toxicity has not been sufficiently investigated. Limited evidence, including data from Western Canadian primary STPs, indicates primary effluents are generally acutely lethal.

Secondary and lagoon treatment plants produce effluents of variable quality. Lethality is not, therefore, related simply to the type of treatment process involved (i.e., secondary or lagoon), but to conditions specific to each plant. Although the data are often incomplete, effluent constituents and plant operating conditions corresponding to the toxicity studies are discussed in Sections 4.0 to 7.0, and provide evidence for the factors leading to STP effluent toxicity.

Chronic toxicity data for STP effluents are lacking. Only the Galt plant effluent in Ontario has been evaluated for sublethal toxicity where the U.S. EPA Ceriodaphnia reproductive test was used.

FIGURE 2.6
Toxicity of Non-chlorinated Effluents from
Lagoon Sewage Treatment Plants in Western Canada
to Rainbow Trout



* chlorinated effluent, but tertiary treatment likely removed most TRC (See 2.2.3)

3.0 IN SITU BIOMONITORING OF CANADIAN STPs

3.1 Ontario STPs

There have only been four in situ studies conducted in Ontario , where fish have been placed in cages in the receiving water. Table 3.1 demonstrates that Walkerton, London (Greenway), Stratford, and Tillsonburg STPs may all produce effluents which are lethal to fish placed in the effluent plume. At Walkerton and Greenway, these effects are fairly minimal and restricted to stations immediately below the outfall. The STP at Stratford, however, appears to produce an effluent with more distant downstream lethality than at other plants, with 66% mortality of rainbow trout at 475 m downstream after 120 h of exposure. At the Tillsonburg STP, 50% mortality of rainbow trout occurred as far as 53 m downstream of the discharge after 6.4 hours during chlorine disinfection. The zone of lethality was reduced to 4.5 m and 22 m when alternate disinfection procedures were followed (i.e., Ultra Violet (U.V.) and sodium bromide/chlorine, respectively). Toxicity observed with U.V. disinfection in use was attributed to the discharge of raw sewage bypass.

3.2 Canadian STPs

Clarke et al. (1977) conducted an in situ study at the North End Treatment Plant in Winnipeg, Manitoba (Table 3.2). Effluent chlorination increased mortality of caged juvenile black bullheads immediately below the STP outfall, but few to no effects were observed 1.2 km downstream with or without chlorination over four days.

Osborne et al. (1981) placed rainbow trout in the Sheep River, Alberta, to determine the impact of the Turner Valley secondary treatment plant. No mortality occurred over 24 hours when non-chlorinated sewage was discharged, but 100% mortality occurred 5 and 50 m from the outfall during a 24-hour period of chlorination.

3.3 Summary

Although only four Ontario STPs have been investigated with respect to their effluent effects on receiving waters, all four have demonstrated some degree of fish lethality in the effluent plume. Tests at Western Canadian STPs also showed that, under some

TABLE 3.1: <u>IN SITU</u> TOXICITY TESTING OF ONTARIO STP EFFLUENT LETHALITY

Location/ Receiving Water	Test Date (d/m/y)	Test Species	Exposure Method	Exposure Location	Total NH_3-N (mg/L)	pH	TRC (ug/L)	Response	Comments	Reference
Greenway (Thames River)	10.11.79	Rainbow Trout	Cage	Upstream Control				0% mort. after 18 hrs*	*Exposure terminated after 18 hrs due to severe rainfall conditions	OMOE (1980)
				28 m				20% mort. after 18 hrs		
				65 m				0% mort. after 18 hrs		
Stratford (Avon River)	08-10.08.82	Rainbow Trout L: 6.8 cm W: 3.8 gm	Cage	Upstream Control	0.2-0.7	8.2-8.4	0	0% mort. after 96 hrs	At 78.5 m downstream station, mortality results reflect conditions at extreme edge of plume. This suggests no zone of passage for fish to avoid toxic plume. Residual chlorine up to 5 ug/L detected 572 m downstream.	Flood <u>et al.</u> (1984a)
				17.3 m	4.4-7.5	7.5-7.7	168-348	LT50 = 2 hrs 98% mort. after 6 hrs 100% mort. after 20 hrs LT50 = 12 hrs		
				78.5 m (1)	1.7-6.5	7.6-8.0	0-260	88% mort. after 20 hrs 100% mort. after 24 hrs LT50 = 12.5 hrs		
				78.5 m (2)	2.0-6.9	7.8-8.0	0-48	82% mort. after 20 hrs 100% mort. after 24 hrs		
				209 m	3.3-4.7	7.7-7.9	3-103	32% mort. after 20 hrs 100% mort. after 30 hrs		
				475 m	1.8-4-4	7.7-7.9	0-37	2% mort. after 48 hrs 66% mort. after 120 hrs		
Tillsonburg (Big Otter Creek)	29.08-09.82	Rainbow Trout L: 15.5 cm W: 45.8 gm	Cage	Upstream Control			ND	0% mort. after 10 hrs	Chlorination treatment #1. All stations, except control, demonstrated 100% mortality within 24 hrs of exposure.	Flood <u>et al.</u> (1984b)
				4.5 m			109-210	LT50 = 5.3 h		
				22 m			165-218	LT 50 = 4 h		
				38.5 m			222-292	LT50 = 4 h		
				53 m			184-230	LT50 = 6.4 h		
	27-29.08.82			Upstream Control			ND	0% mort. after 48 hrs	U-V Treatment #1. Untreated sewage discharged along with final effluent due to storm event	
				4.5 m			ND	14% mort. after 48 hrs		
				22 m			ND	10% mort. after 48 hrs		
				38.5 m			ND	4% mort. after 48 hrs		
				53 m			ND	6% mort. after 48 hrs	U-V Treatment #2	
	03-04.09.82			Upstream Control			ND	0% mort. after 48 hrs		
				4.5 m			ND	0% mort. after 48 hrs		
				22 m			ND	0% mort. after 48 hrs		
				38.5 m			ND	0% mort. after 48 hrs		
				53 m			ND	0% mort. after 48 hrs		
	01-03.09.82			Upstream Control			0	0% mort. after	Sodium bromide/chlor. trt.	
				4.5 m			15-18	LT50 = less than 4 hrs	100% mort. after 18 hrs	
				22 m (1)			?15-18	2% mort. after 48 hrs	Outside plume	
				22 m (2)			15-18	18% mort. after 48 hrs	In plume	
				38.5 m				*Bucket attacked by blue heron	Br levels were 33-41 ug/L	
Walkerton (Saugeen River)	10-11.07.77	Rosy Face Shiners	Cage	Upstream Control	0.038	8.23	0	12.5% mort. after 48 hrs	River: 10.6 m^3/sec Effl: 0.07 m^3/sec	OMOE (1979)
				17 m	1.65	7.89	21	56% mort. after 48 hrs		
				183 m	0.506	8.09	4	53% mort. after 48 hrs		
				333 m	0.383	8.13	0	0% mort. after 48 hrs		

TRC - total residual chlorine; method of analysis not specified except at Tillsonburg where amperometric titration was employed.
LT50 - duration of exposure which is lethal to 50% of exposed organisms.

TABLE 3.2: EFFLUENT TOXICITY OF WINNIPEG STP (NORTH END) TO JUVENILE BLACK BULLHEADS HELD IN CAGES IN THE RED RIVER AT VARYING DISTANCES FROM OUTFALL (Clarke _et al._, 1977)

Test Date (d/m/y)	Location	TRC (ug/L)	Response
29.07.74*	40 m upstream	0	0% mortality after 96 hrs
	Outfall	0	100% mortality after 24 hrs
	0.23 km downstream	0.5	100% mortality after 24 hrs
	0.52 km downstream	0.7	100% mortality after 24 hrs
	1.16 km downstream	0	0% mortality after 96 hrs
	1.52-1.65 km downstream	0.6	0% mortality after 96 hrs
07.08.74**	40 m upstream	0	0% mortality after 96 hrs
	Outfall	0	0% mortality after 96 hrs
	0.52 km downstream	0	10% mort. after 96 hrs then no change
	1.16 km downstream	0	5% mort. after 96 hrs then no change
	2.5 km downstream	0	5% mort. after 96 hrs then no change
17.09.74***	40 m upstream	0	0% mortality after 96 hrs
	Outfall	1.39	0% mortality after 24 hrs
		0	30% mortality after 48 hrs
		0	70% mortality after 96 hrs
	0.23 km downstream	0-0.03	0% mortality after 96 hrs
	0.52 km downstream	0	0% mortality after 96 hrs
	1.52-1.65 km downstream	0	0% mortality after 96 hrs
	2.15 km downstream	0	0% mortality after 96 hrs

* 5 mg/L chlorine added continuously to effluent (downstream measurements of TRC very inconsistent).

** No chlorine added to effluent.

*** 8 mg/L chlorine added intermittently to effluent.

TRC - total residual chlorine measured by amperometric titration.

conditions (e.g., chlorine disinfection), in-stream lethality can occur. Further discussion of the effluent components leading to lethality follows in Section 4.0.

4.0 FACTORS AFFECTING STP EFFLUENT TOXICITY

4.1 Ammonia

4.1.1 Aquatic Chemistry of Ammonia

Ammonia is present in wastewaters and naturally occurs in surface waters. It is produced largely by deamination of organic nitrogen-containing compounds and by hydrolysis of urea (APHA, 1985). Once formed, it maintains an equilibrium between the ionized (ammonium, NH_4^+) and un-ionized (ammonia, NH_3) species. This equilibrium is affected primarily by pH and temperature according to the following equation (Emerson et al., 1975):

$$\text{Fraction of Total Ammonia in Un-ionized Form} = \frac{1}{1 + 10^{(pKa-pH)}}$$

where: $pKa = 0.09 + \frac{2,730}{273+T}$ and $T = {}^{o}C$

4.1.2 Toxicity of Ammonia in Ontario STP Effluents

Ammonia was the most commonly cited cause of lethality in laboratory toxicity tests of nonchlorinated STP effluents in Canada. Fava et al. (1985) measured many physical and chemical parameters in a toxicity test of whole and liquid phase sewage sludges from 12 wastewater treatment plants in the U.S. Ammonia-nitrogen was the only constituent identified as a major contributor to toxicity to Atlantic silversides and grass shrimp when whole sludge was compared to the filtered liquid phase. This was due to the fact that ammonia was the only parameter identified of 142 separate analytical determinations which was not dramatically removed, resulting in similar toxicity between the whole and liquid phase sludges. Primary treatment is not effective in removing NH_3. Presented in Tables 4.1a and 4.1b are the levels of total ammonia measured in lethal and non-lethal samples from primary, secondary and lagoon STPs in Ontario and Western Canada. Although many non-lethal samples also contained high ammonia levels, the lethal samples at each STP generally contained higher ammonia levels than the non-lethal samples.

TABLE 4.1a: TOXICITY OF FINAL EFFLUENTS FROM ONTARIO STP's AS RELATED TO TOTAL AMMONIA LEVELS

Total Ammonia (mg/L)	Waterloo	Welland*	Wingham	Mitchell	Tavistock	Listowel	Markdale	Galt	Other Ontario Plants (summer)	Other Ontario Plants (winter)
0 to 2	xxxxxxx xxxxxx	xx		x					xxxxxxx xxxxxo	xxxxxx
2.1 to 4	xxxx	xx	xx			x	x	x	xxo	xx
4.1 to 6		xxx	xxx	xo	x				o	xx
6.1 to 8		xxx				x			xx	o
8.1 to 10		xxx	xxo	x	o	xx		o	xxo	oo
10.1 to 12		xo	o	o	x	xxxxx	xxo		o	o
12.1 to 14			o				xoo	o	o	xooo
14.1 to 16			o		o		oo	xxxx		oooo
16.1 to 18					o			x		
18.1 to 20								xxxx		
20.1 to 22							o	x		
22.1 to 24								xxxo	**	
24.1 to 26										
26.1 to 28								ooxx		o
28.1 to 30										
30.1 to 32										
32.1 to 34										
34.1 to 36										
36.1+										

* Five samples were acutely lethal, but only the one indicated remained lethal after dechlorination.
** Three-quarters of non-lethal samples in this concentration range were toxic at 168 h and in reproduction tests.
x = Non-toxic (< 50% mortality).
o = Toxic (> 50% mortality).

TABLE 4.1b: TOXICITY OF FINAL EFFLUENTS FROM CANADIAN STP's AS RELATED TO TOTAL AMMONIA LEVELS

		British Columbia										Sask.	Manitoba
Total Ammonia (mg/L)	Penticton	Clinton	Williams Lake	Iona Island	Cache Creek	Prince George	Mission	Annacis Island	Lions Gate	Lulu Island	Others	Regina	Winnipeg
0 to 2		xx	xxxx										x
2.1 to 4													
4.1 to 6						x							
6.1 to 8						x						o	
8.1 to 10				oo		x	x					xxxxoo	
10.1 to 12				ooo			x				oo		
12.1 to 14							x	o			o	xoo	
14.1 to 16							xx				o		xx
16.1 to 18	o					x	xx		oo		o	ooo	xoo
18.1 to 20								oo				o	xxo
20.1 to 22	ooo						x	ooooo		ooo		ooo	o
22.1 to 24	oo											xxoo	o
24.1 to 26	o				o								
26.1 to 28	o				o			oo				oo	
28.1 to 30					o							xoooooo	
30.1 to 32					o							xxoo	
32.1 to 34					o							x	
34.1 to 36					oo							oo	
36.1+					o								

x = Non-toxic (< 50% mortality).

o = Toxic (> 50% mortality).

In order to estimate what concentration of ammonia represented the lethal threshold (> 50% mortality), the percent lethal samples was plotted against total ammonia concentrations at each 2 mg/L increment in Figure 4.1. When the total ammonia concentrations fell within the 10 to 12 mg/L range, 50% of the effluent samples were lethal. In general, as ammonia concentrations further increased, the incidence of lethality among effluents continued to increase and approach 100%. Based on this analysis, 10 mg/L total ammonia nitrogen was taken to represent the best estimated threshold for lethality.

Most wastewater treatment plants in Ontario are able to reduce effluent ammonia concentrations to less than 10 mg/L for the majority of the year (Table 4.2). Sixty-three of 88 lagoons were rated as discharging effluents in which ammonia concentrations never exceeded 10 mg/L during the year. Another 12 lagoons exceeded 10 mg/L of effluent ammonia for one to three months of the year. Both seasonal and continuous lagoons were included in this evaluation, the methodology of which is described in Section 7.1. In the secondary treatment category, 45 of 86 plants never exceeded 10 mg/L of effluent ammonia during the year, while an additional 19 STPs exceeded 10 mg/L for one to three months of the year. Only one of six primary treatment plants was able to limit the months that ammonia exceeded 10 mg/L to three months or less, but three other primary plants exceeded 10 mg/L of effluent ammonia for four to six months of the year. With the exception of some primary plants, the monthly data suggest that the majority of wastewater treatment plants in Ontario are capable of reducing effluent ammonia concentrations to less than 10 mg/L throughout the year.

Un-ionized ammonia is the toxic form of ammonia. Concentrations of 0.1 to 3.4 mg/L are lethal to fish (Craig, 1985). The level of un-ionized ammonia for each Canadian STP effluent often could not be calculated due to a lack of total-NH_3, pH or temperature data. However, an approximate concentration of un-ionized ammonia corresponding to 10 mg/L total ammonia can be calculated based on a temperature of 15^{o}C for effluents evaluated under standard toxicity test conditions, and an estimate of pH. Although the initial pH of the test solutions averaged 7.5, it is known that the pH usually rises rapidly within the first 24 hours of static testing with STP effluent (BEAK, unpublished data; Baird et al., 1979). Assuming a conservative 0.3 unit rise in pH (to 7.8) and 15^{o}C as the average test temperature, a 10 mg/L total ammonia level would correspond with 0.17 mg/L in the un-ionized form. This concentration falls in the lower end of the range of

FIGURE 4.1 Total Ammonia-Nitrogen vs. Relative Frequency of Acutely Lethal Effluent Samples

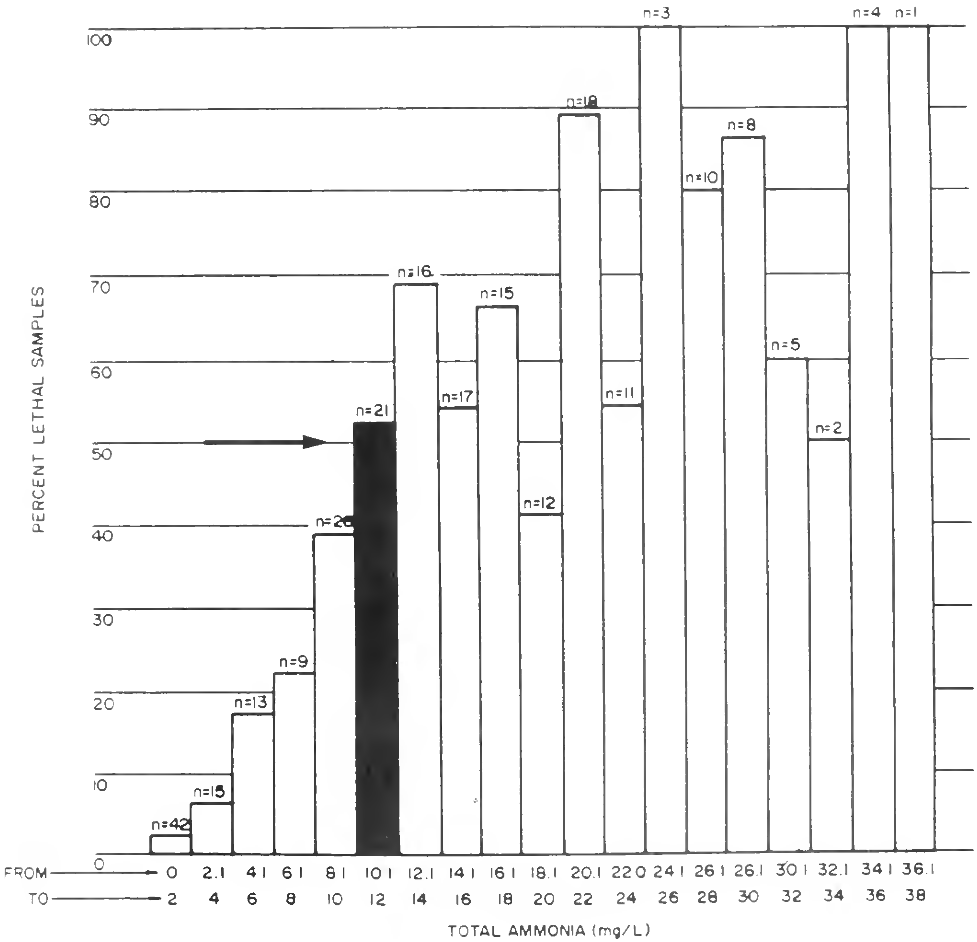


TABLE 4.2: MATRIX OF ONTARIO STPs ACCORDING TO MONTHLY TOTAL AMMONIA CONCENTRATIONS* IN FINAL EFFLUENT

Months per Year Where Total Ammonia Greater than 10 mg/L	Plant Type			
	Primary	Secondary	Lagoon	Total
0	1	45	63	109
1-3	0	19	12	31
4-6	3	10	12	25
7-9	1	6	0	7
10-12	1	6	1	8

* Monthly data only available for 180 of 401 Ontario STPs.

LC50's reported for rainbow trout (0.1 to 1.44 mg/L; Craig, 1985), and justifies the 10 mg/L level of total ammonia as an estimated threshold for lethality.

The occurrence of total ammonia at greater than 10 mg/L does not necessarily result in an acutely lethal effluent (Table 4.1), since mortality results from the un-ionized ammonia concentration which is dependent on the pH and temperature of the solution. The 10 mg/L level was a useful number for the purposes of this study, to provide a basis for the categorization of Ontario STPs. It is not proposed as a regulatory standard but, instead, as an indicator of a greater than 50% chance of effluent lethality.

4.1.3 Toxicity of STP Effluents Following Ammonia Removal

Zeolites, such as clinoptilolite, are resins containing silica and aluminum, which occur naturally in the earth. Zeolites have been adapted for use in water softening since the early 1900's. Ammonia removal by clinoptilolite has been recommended for treatment of water in aquaculture systems due to its preferential selectivity for the ammonium ion (Dryden and Weatherley, 1987). It also removes other cations such as K^+, Na^+, Ca^{2+} and Mg^{2+} (Dryden and Weatherley, 1987), however, as well as some cationic metals (e.g., Co^{3+}, Cu^{2+} and Zn^{2+}) (Barrer and Townsend, 1976). The exchange capacity of clinoptilolite depends on such factors as the ionic strength and composition of the solution (Dryden and Weatherley, 1987).

One sample of secondary STP effluent from Welland, Ontario was treated with clinoptilolite resin to remove ammonium. The LC50 rose to 71% as compared to 8% for the chlorinated effluent and 25% for the dechlorinated effluent. Residual toxicity after chlorine and ammonia removal indicated the presence of other toxic contaminants. Two lethal effluent samples from Galt STP became non-lethal after clinoptilolite treatment (Canviro, report in progress). Esvelt et al. (1973) calculated an LC50 of 76% for an STP effluent which subsequently became non-acutely lethal after clinoptilolite treatment. Total ammonia nitrogen was reduced from 17.5 to 1.1 mg/L in the process. The studies above did not measure the removal of other cations.

4.1.4 Evidence of Ammonia Toxicity in Receiving Waters

Very few studies have been reported of ammonia-induced lethality in waters receiving STP effluents. This is mostly due to the fact that most STPs chlorinate their final

effluents for disinfection, and separation of the relative toxic contribution of each component (NH_3 and TRC) was not investigated in these studies (Section 4.2). The following results from experiments conducted in the receiving waters of STPs are circumstantial, at best, with respect to ammonia toxicity. Clearly, more thorough in-stream ammonia measurements in relation to observed toxicity are necessary.

At Tillsonburg, Flood et al. (1984b) examined the toxicity to caged rainbow trout of U-V disinfected effluent (Table 3.1). Since no residual chlorine was detected, the mortality observed during one UV treatment was due to some other contaminant(s). Some raw sewage bypassed treatment at the time due to a storm event, and was discharged to the river. Ammonia levels in the river were reportedly an order of magnitude less than lethal levels, but no concentrations were given. No other parameters measured could be identified as the toxic agent.

In Winnipeg, the North End STP effluent was lethal to 5 to 10% of black bullheads caged in the Red River while no chlorine was added to the effluent. Ammonia was not measured and no explanation was given for the observed lethality.

Servizi and Martens (1974) observed mortality of salmon below a primary treatment plant during periods without chlorination, although survival times were more than ten times shorter when the chlorinator was operating. Toxicity was attributed to ammonia, anionic surfactants and low dissolved oxygen.

Fava et al. (1985) reported un-ionized ammonia of 0.25 mg/L at the outfall of a trickling filter STP in Pueblo, Colorado. Concentrations of approximately 0.15 mg/L un-ionized ammonia were still present 1 km downstream. Mortality of caged fathead minnows was observed (100%) at all stations up to 600 m below the outfall, but was partly attributed to TRC concentrations which averaged 0.08 to 0.06 mg/L over that distance.

4.1.5 Ammonia Persistence

Ammonia is slowly dissipated in receiving waters. Total ammonia at Stratford measured 4.4 to 7.5 mg/L at 17.3 m from the outfall into the Avon River, while 1.8 to 4.4 mg/L were still present after 475 m (Flood et al., 1984a). In the Saugeen River at Walkerton STP, 1.65 mg/L total ammonia was measured at the outfall and 0.38 mg/L was measured

333 m downstream. Fava et al. (1985) found that un-ionized ammonia from an STP in Colorado was 0.25 mg/L near the outfall and 0.15 mg/L 1 km away. An earlier study in Pueblo, Colorado concluded that dilution as opposed to de-nitrification accounted for decreasing ammonia levels downstream (Lee et al., 1982). Slow nitrification of ammonia could, therefore, result in persistent toxic effects downstream of STP discharges.

4.2 Total Residual Chlorine

Since chlorination occurs as a separate process following waste treatment, all historical data concerning chlorinated effluent toxicity are discussed here as a separate section.

The evaluation of sewage treatment plant effluent toxicity necessitates a discussion of chlorination practices. Chlorination is essentially the only STP disinfection method practiced in Canada due to its lower cost over alternative methods such as ozonation (Tonelli et al., 1981). Disinfection is completed just prior to effluent discharge and, since chlorine is very toxic to fish, a near-field zone of lethality and a further field of sublethal impact on the receiving water is anticipated.

4.2.1 Aquatic Chemistry of TRC and Methods of Analysis

Chlorine, when added to water, normally tends to form hypochlorous acid and hypochlorite ion. These free chlorine forms react readily with ammonia and certain nitrogenous compounds to form combined chlorine, particularly chloramines. Total residual chlorine (TRC) measured in wastewater or receiving waters is the summation of free and combined forms (APHA, 1985).

Several methods exist for the analysis of TRC. The iodometric and DPD methods are less sensitive than the amperometric method, while the orthotolidine procedure is considered very inaccurate (Collins et al., 1973; Bellanca and Bailey, 1977; Servizi, 1979; APHA, 1985). The iodometric methods are suitable for total chlorine concentrations greater than 1 mg/L. The DPD and amperometric methods are useful in differentiating between free and combined chlorine concentrations, although amperometric titration is more complex. While most studies not reporting TRC according to amperometric titration were eliminated from consideration, a few studies using DPD or iodometric methods were included, where the information seemed reliable and necessary to this review.

4.2.2 Canadian Studies of Chlorinated STP Effluent Toxicity

Appendix A (Tables A1 and A2) includes studies of the toxicity of chlorinated effluents from Ontario and other Canadian STPs, respectively. These results have been plotted in Figures 4.2 and 4.3 as the number of toxic samples out of the total number of samples analyzed for non-chlorinated, chlorinated and dechlorinated effluents. It appears from the figures (particularly 4.3) that chlorination is not the primary source of toxicity in effluents generally tested in the laboratory, since acute lethality of non-chlorinated or dechlorinated samples is not significantly greater than the same sample chlorinated. occurrence of acutely lethal samples is not greatly increased by chlorination. This is due to the fact that most of the toxicity tests were conducted as static tests and, therefore, the chlorine residual was dissipated during sample handling and storage, as well as aeration during tests. Ammonia levels in the toxic effluents of Western Canadian STPs were measured at greater than 10 mg/L, and probably account for mortality observed in those tests of chlorinated, dechlorinated and non-chlorinated effluents, thereby masking effects due to chlorine.

Cairns and Conn (1979) demonstrated that TRC is a major source of acute toxicity through on-site, continuous-flow tests at the Brampton Experimental Station. All 12 chlorinated effluent tests resulted in acute lethality, while only two of 17 non-chlorinated effluents were lethal. Clearly, the presence of TRC results in lethality, but it is often rapidly dissipated to non-toxic levels in static tests. Continuous flowtests conducted by Arthur et al. (1975) in Minnesota also demonstrated chlorine - induced lethality of a secondary sewage treatment plant effluent to fish and invertebrates.

4.2.3 TRC Toxicity

Many experiments have been conducted to determine the toxicity of chlorine residuals to aquatic organisms. Reviewers of the subject (Brungs, 1973; EPS, 1978) concluded that residual chlorine is acutely toxic at levels as low as 0.01 or 0.02 mg/L, although most LC50's reported for fish and invertebrates are as much as 0.08 and 0.3 mg/L, respectively. Chronic effects are reported to occur as low as 0.001 mg/L (behavioural avoidance), but again, most effects were observed at higher concentrations (greater than 0.01 mg/L). The majority of data were from studies of chlorine in wastewaters where possible additive or synergistic effects from other contaminants were ignored and the toxic effects of TRC may even have been overestimated.

FIGURE 4.2
Toxicity of Chlorinated and Dechlorinated Effluents
Compared to Nonchlorinated Effluents
from Ontario STP's

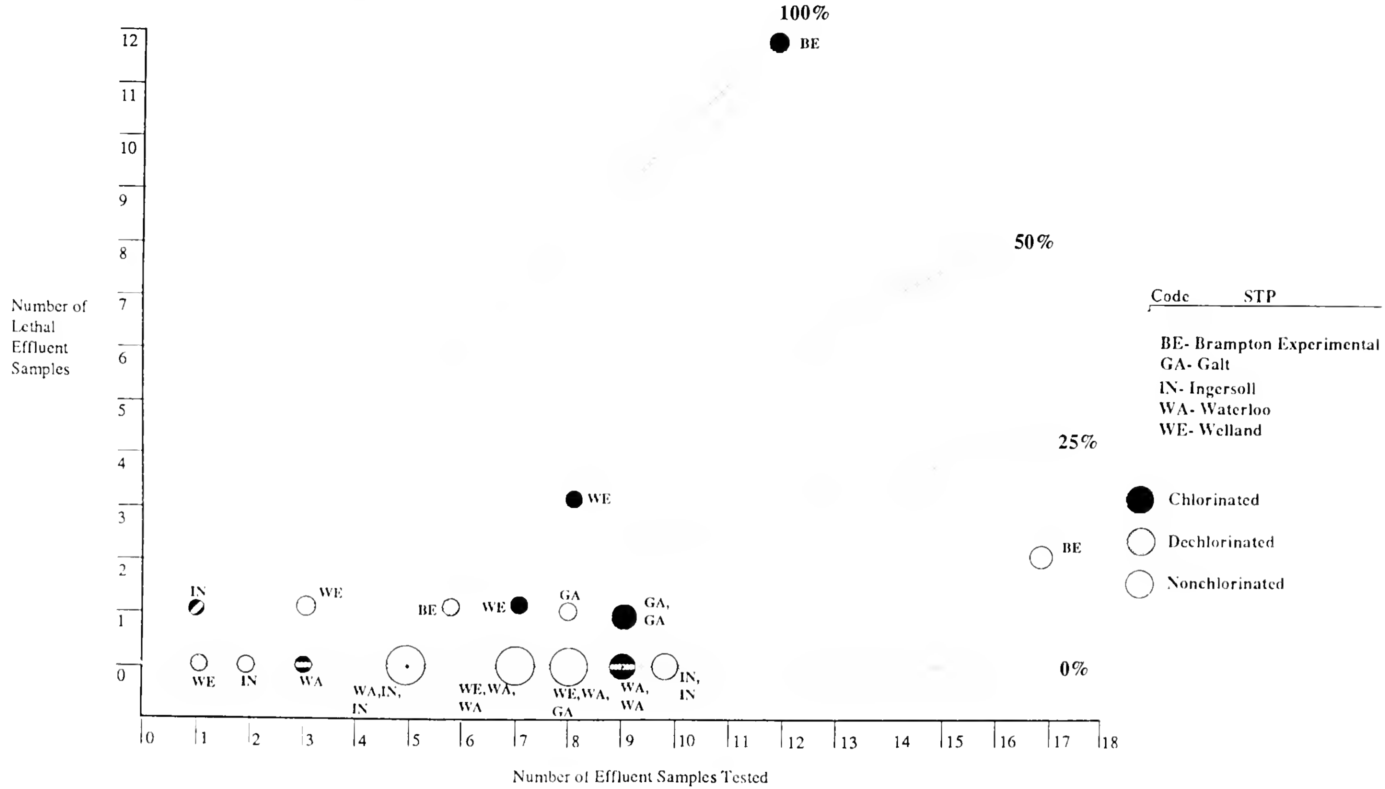
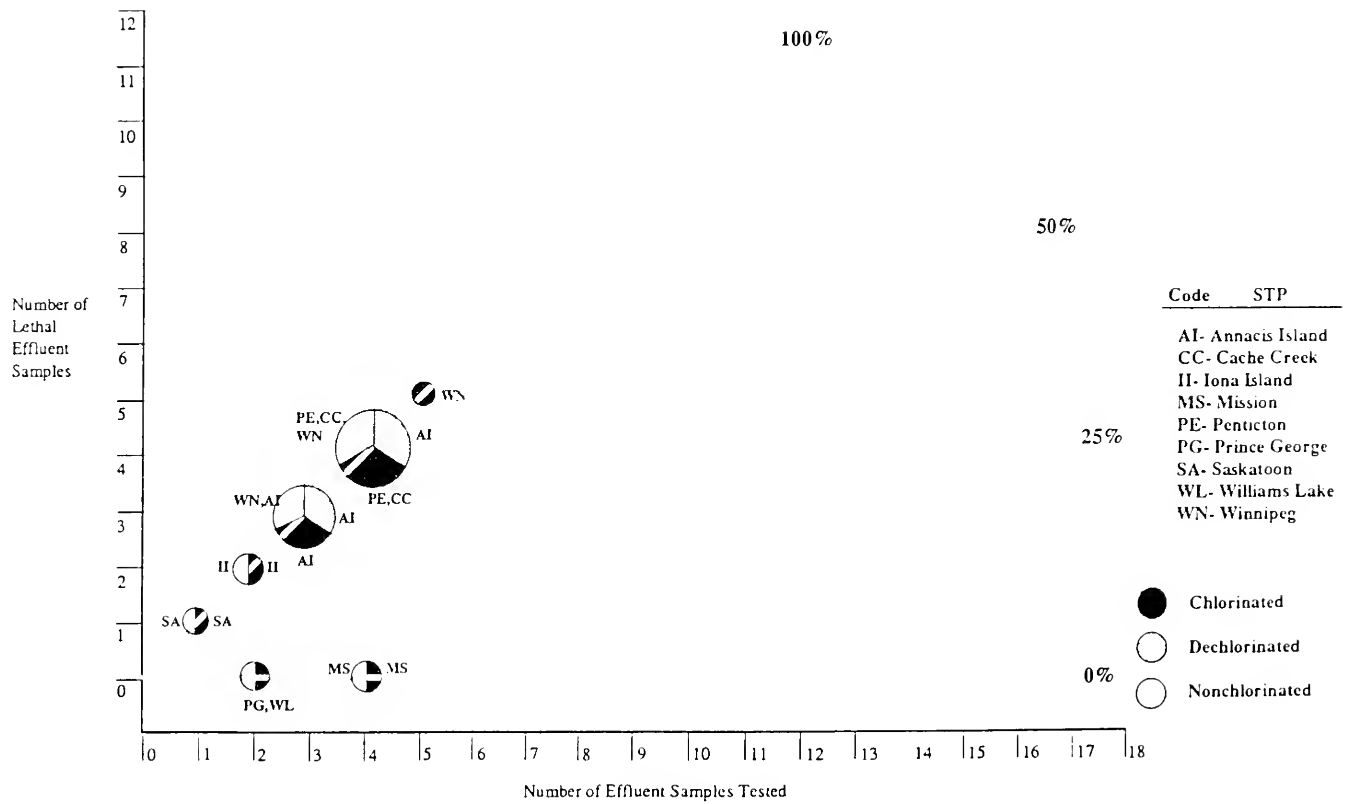


FIGURE 4.3
Toxicity of Chlorinated and Dechlorinated STP Effluents Compared to Nonchlorinated Effluents in Western Canada



Laboratory toxicity tests conducted with clean dilution water are in fairly good agreement, however. Arthur and Eaton (1971) identified the acute LC50 between 0.085 and 0.154 mg TRC/L for fathead minnows, while the LC50 for amphipods was 0.22 mg TRC/L. The chronic threshold values from the same study were 0.043 mg/L for fathead minnows (spawning impairment) and 0.035 mg/L for amphipods (reduced survival and impaired reproduction). Larson et al. (1978) tested chloramine toxicity to adult rainbow trout and found no evidence of harmful effects at 0.05 mg/L, but threshold concentrations for growth of alevins and juveniles were between 0.01 and 0.022 mg/L.

Considering all the available data, especially those based on amperometric measurements, the acute and chronic thresholds for aquatic toxicity of total residual chlorine can be estimated as approximately 0.04 (lowest LC50 of 0.085 x safety factor of 0.5) and 0.01 mg/L, respectively.

4.2.4 Toxicity of Dechlorinated Effluents

The importance of TRC in STP effluent toxicity has been determined in some studies by comparison testing of nonchlorinated, chlorinated and dechlorinated effluents. The process of dechlorination involves the application of chemical agents such as sulphur dioxide (SO_2), sodium thiosulphite ($Na_2S_2O_3$), sodium sulphite (Na_2SO_3), or sodium bisulphite ($NaHSO_3$), or the use of a granular activated carbon filter bed to remove TRC. The aquatic chemistry involved with each method is discussed in Appendix B.

The tables in Appendix A (Tables A1 and A2) include Canadian studies where dechlorinated effluents were tested for toxicity to aquatic organisms. The results of these studies generally indicated that dechlorination reduced or eliminated chlorine-induced toxicity.

Ward and DeGraeve (1978) found that the lowest total residual chlorine concentration in wastewater from a trickling filter process that caused lethality in fathead minnows was 0.165 mg/L. Dechlorination with sulphur dioxide eliminated the lethal effects associated with chlorine, since mortality rates in dechlorinated and non-chlorinated effluents were similar. Because some mortality was associated with undiluted non-chlorinated effluent, one or more contaminants must have been present in lethal quantity. Ammonia was a likely factor (Section 4.1) at 9.3, 9.1 and 9.2 mg total NH_3-N/L in non-chlorinated,

chlorinated and dechlorinated effluents, respectively. Metals and cyanide were also cited as possible contributors, but were unconfirmed.

Arthur et al. (1975) reported lowest mean TRC concentrations in secondary effluent causing measurable chronic effects at 0.042 mg/L for fathead minnows (survival), 0.019 mg/L for amphipods (reproduction), and about 0.01 mg/L for Daphnia (survival). Non-chlorinated and dechlorinated effluents were not acutely toxic to half of species tested, or caused only partial mortality at 100% and 75% concentrations. In some cases, the dechlorinated effluents were even less toxic than the non-chlorinated ones, suggesting that other toxic components or interactions were removed through dechlorination. Mortality in some acute tests of non-chlorinated effluent was attributed to low oxygen levels. Esvelt et al. (1973) also demonstrated that dechlorination of wastewaters removes chlorine-induced toxicity to shiners and sticklebacks, and also removed some other toxic components. The mean LC50 for primary plant effluents before chlorination was 42%, while after dechlorination it was 53%. The chlorinated effluent LC50 was 34%.

Martens and Servizi (1975) found that survival time for sockeye and pink salmon fingerlings in dechlorinated primary sewage effluent was significantly greater than in chlorinated effluent.

Zillich (1972) found that the addition of sodium thiosulfate greatly reduced but did not eliminate the toxicity of a chlorinated STP effluent in Wyoming, MI, during an on-site toxicity testing study. Similarly, Tonelli et al. (1981) demonstrated that chemical dechlorination (sodium sulphite) removed acute lethality of STP effluent to rainbow trout.

The results cited above are evidence that chlorination enhances primary and secondary effluent toxicity but, in some cases, lethality was caused by other factors present in the non-chlorinated effluents. Dechlorination removes chlorine-induced toxicity and may also partially remove or detoxify other toxicants or eliminate toxicant interactions contributing to effluent lethality.

4.2.5 Evidence of Chlorine Toxicity in Receiving Waters

The MOE cage study at Tillsonburg STP (Flood et al., 1984b) demonstrated TRC-induced lethality in receiving waters during chlorination, while U.V. disinfection reduced or

eliminated mortality of rainbow trout. TRC levels and trout lethality were only monitored over a 53-m distance downstream of the discharge. Therefore, it is not known how far the TRC effects persisted. Combined chlorine/bromine treatment caused greater acute lethality to rainbow trout relative to chlorine treatment alone.

In a similar study, Osborne et al. (1981) found 100% mortality among caged rainbow trout 5 m and 50 m from a secondary STP outfall in Alberta. Partial mortality (up to 40%) occurred for 100 m downstream. When chlorination was terminated, no mortalities occurred at the same locations during 24 hours of exposure. Indigenous fish were collected from the same river site in areas where mortality was expected, indicating that short exposures can be tolerated and/or acclimation mechanisms increased tolerance.

Reports by Tsai (1968, 1970, 1973) are frequently cited examples of chlorinated effluent effects on receiving waters, but residual chlorine was not measured in the 1968 and 1970 studies, and was measured by the orthotolidine method in 1973. As discussed earlier, the orthotolidine method is unreliable.

Servizi and Martens (1974) reported in-stream mortality among sockeye and pink salmon below the outfalls of primary and lagoon treatment systems. Median survival times were lengthened, but mortality still occurred, when chlorination was halted.

Significant avoidance of 0.006 mg/L chloramine was demonstrated by killifish (*Oryzias latipes*) in the laboratory (Hidaka and Tatsukawa, 1985).

Behavioural avoidance of chlorinated waters has been demonstrated by fish at acutely toxic and lesser concentrations (Brooks and Seegert, 1978; Larson et al., 1978). Grieve et al. (1978) noted that white bass in Lake Ontario avoided areas of TRC above 35 ug/L during short-term chlorination periods at a hydro generating station. Fish can tolerate short exposures to toxic TRC concentrations (Lee et al., 1982). Indigenous fish have been observed making brief excursions into chlorinated effluent plumes (Osborne et al., 1981; Fava et al., 1985).

4.2.6 TRC Persistence

Some authors claim that chlorine residuals may remain toxic for a considerable time in the environment (EPS, 1978). Brungs (1973) also concluded that "residual chlorine

persists for periods longer than the few minutes or hours indicated by some authorities", but it is not clear on what information these conclusions are based. The studies where amperometric analyses of TRC was the method of chlorine measurement in receiving waters are discussed below.

Chlorine persistence depends on sunlight, stream depth, turbulence, temperature and type of residual. The half-life of 3 mg/L free chlorine was 8 to 28 minutes when exposed to open air and sun, but was ten-fold greater away from sunlight (indoors) and without stirring (Snoeyink and Markus, 1973, 1974; cited in Johnson, 1976).

Combined chlorine decay rates are a factor of ten slower than free chlorine (Snoeyink and Markus, 1973; cited in Johnson, 1976). Bender et al. (1975; cited in Johnson, 1976) noted monochloramine was more persistent than free chlorine in estuarine water.

TRC analyses in receiving waters have indicated variable persistence. Servizi and Martens (1974) reported residuals as high as 1.2 mg/L at 122 m from the outfall and 0.24 mg/L 274 m below a primary plant. TRC levels were reported as high as 0.79 mg/L 155 m past a lagoon outfall. Most residual levels were much less downstream from both STPs. The TRC levels reported are also much higher than is likely released from most Ontario STPs where effluent residuals are usually maintained around 0.5 mg/L, and would be less once diluted by the receiving water.

In Colorado, Lee et al. (1982) measured variable TRC (0.02 to 0.25 mg/L) in an STP effluent. The EPA redbook guideline of 0.01 mg/L was not met until 3.9 km. Dilution was the primary cause of TRC dissipation for 2.6 km downstream. Volatillity accounted for more than half the dissipation due to factors other than dilution. The stream was highly turbid, therefore little phototransformation was expected.

At Tillsonburg, Ontario, TRC was measured in the Big Otter Creek below the STP outfall. The concentrations detected did not differ greatly between the station immediately below the outfall (0.109 to 0.210 mg/L) and the furthest station downstream (0.184 to 0.230 mg/L), indicating little dissipation. The furthest station was merely 53 m from the outfall, however, which may have been an insufficient distance to adequately reflect TRC behaviour downstream.

Clarke et al. (1977) detected residues of chlorine in the Red River after the addition of 5 mg/L to the effluent. TRC levels of 0.5, 0.7 and 0.6 mg/L were measured 0.23, 0.52 and 1.6 km downstream, but none was detected at 1.16 km. Intermittent chlorination at 8 mg/L in the effluent also resulted in inconsistent residues downstream.

Servizi and Martens (1974) conducted a simple test in 40-L containers to measure the TRC dissipation rates of various effluent dilutions. TRC was reduced three- to ten-fold within one day. Given the turbulence, dilution and various environmental degradation processes within a receiving water body, it is not anticipated that TRC would normally have widespread effects. Most in situ studies, which include reliable TRC analyses, show lethal effects are generally contained in the near vicinity (less than 1 km) of the STP.

4.2.7 Toxicity of Free Chlorine vs. Chloramines

There was some disagreement concerning the relative toxicities of free versus combined chlorine in reports from 1950 to the early 1970's (Brooks and Seegert, 1978), but analytical methods have improved substantially since the earlier studies were conducted. Recent reports indicate free chlorine is more toxic than chloramines.

Chloramines were several times less toxic to rainbow trout, coho salmon, golden shiners and channel catfish than free chlorine (Heath, 1978; amperometric analysis). Hazel et al. (1982; DPD analysis) also found free chlorine to be the more toxic form in tests with crayfish.

4.2.8 Chlorination of Organics

Kopperman et al. (1976) reviewed the concentrations of organics found in STP effluents. Most contaminants were found in the low ug/L range. One study reviewed by Kopperman et al. reported a 15 to 80% removal of influent chloro-organics due to secondary treatment (average 43%) and only a slight increase (average 19%) after chlorination. Low concentrations of organochlorine contaminant measured in Canadian STP effluents were reported by Melcer (1986) and Craig et al. (1983). Jolley (1975) separated over 50 chlorine-containing organics in a secondary effluent which had been chlorinated to a 1 mg/L chlorine residual. Approximately 1% of the chlorine dosage produced chlorinated organic compounds at 1 to 2 mg/L residuals, but all of the 17 individual compounds identified were at concentrations less than 5 ug/L.

4.2.9 Toxicity Relationship of TRC and NH_3 in Receiving Waters

The aquatic toxicity of ammonia and chlorine have generally been studied separately in STP effluent testing, even though both components have repeatedly demonstrated toxicity. Logically, it would be anticipated that both factors simultaneously contribute to receiving water effects. This can be confirmed by a review of tests where both NH_3 and TRC were monitored.

In studies where lethality due to TRC was noted for some distance in waters receiving STP effluents (i.e., greater than 100 to 200 m^2), NH_3 concentrations were also elevated (Servizi and Martens, 1974; Paller et al., 1983). Conversely, low levels of ammonia were associated with non-persistent chlorine residuals (Servizi and Martens, 1974; OMOE, 1979, 1980; Flood et al., 1984a). An on-site study of effluent chlorination showed that the toxicity of chlorine in wastewater was lowered when denitrification was practised prior to chlorination (Finlayson and Hansen, 1979). A significant inverse relationship was observed between TRC concentrations and the effluent LC50 at total ammonia levels greater than 10 mg/L.

Toxicity below STP outfalls would thus be expected from two sources:

1. the combination of chlorine with ammonia would result in elevated chloramine levels. Since chloramines are more persistent than free chlorine forms, TRC toxicity would be observed further downstream; and
2. un-ionized ammonia itself could contribute to lethality below an STP outfall.

4.3 Other Toxicants

The contribution of total residual chlorine and ammonia to the whole effluent toxicity has been discussed earlier. These two components have been identified as the principal toxicants since both have been measured in effluents at levels exceeding their LC50's to aquatic organisms. Sometimes TRC and NH_3 do not account for all the observed toxicity of an effluent, however, and other contaminant(s) must be present and contributing to toxicity in those circumstances.

It is difficult, in a toxicity assessment of a complex mixture of chemicals, to determine the level at which the chemicals present make a significant contribution to the toxicity of the mixture. This issue has been addressed by a working party of the European Inland Fisheries Advisory Committee (EIFAC) which reviewed all published literature on the toxicity of mixtures to fish and other aquatic life (Alabaster and Lloyd, 1982). Konemann (1979, 1980) has also completed several studies which evaluated the toxicity of organic chemical mixtures to fish. Lloyd (1986) recently examined and evaluated all the available evidence from the above sources and suggested that lethality of a mixture could be predicted based on the number of contaminants present at levels over 0.1 or 0.2 of their "threshold LC50". The threshold LC50 is the concentration which produces no greater than 50% mortality in organisms exposed for an indefinite period of time. This concentration is usually similar to the 96-hour LC50 for fish and the 48-hour LC50 for small invertebrates (Sprague, 1973). Therefore, based on Lloyd's assessment, substances present at concentrations greater than 0.2 of their LC50 are considered to contribute additively to toxicity, and those present at less than 0.2 times their LC50 are expected to show less than an additive contribution. At concentrations below 0.1 of the LC50, pollutants are not expected to exhibit any joint lethal action. This concept has been supported by other authors (Sprague, 1973; Bradley, 1986), and the theory has been incorporated into this review.

While this approach to the toxicity of contaminant mixtures does not take into account possible synergistic or antagonistic toxicity reactions, it does represent a conservative approach to toxicant interaction. It is necessary to focus on the contaminants that are most likely to contribute to lethality and avoid the potentially confounding influence of other compounds present at sublethal concentrations by using "0.2 times the LC50".

Contaminants that have been analyzed in sewage plant effluents include metals, surfactants and industrial organics. The 96-hour LC50 values for Daphnia and rainbow trout to some metals and organics have been taken from the literature and are presented in Table 4.3. Where provincial water quality objectives exist for each chemical, the value has been presented on the table. While other contaminants are likely found in STP effluents, either insufficient effluent concentration data were available, or LC50's have not been reported to allow an assessment of their contribution to toxicity. Where a range of LC50's has been reported, the lowest value was used to calculate the 0.2 fraction.

TABLE 4.3: DOCUMENTED TOXIC CONCENTRATIONS (ug/L) OF VARIOUS METALS AND ORGANICS TO FISH AND INVERTEBRATES

	Water Quality Objectives[14]	Rainbow Trout LC50's	Daphnia LC50's
Inorganics			
Cd[1,2]	0.2	100-2,000	65
Cr[3]	10	3,400-65,500	435-58,700
Cu[1]	5	20-102	80-85
Ni[4]	25	32,000	510-1,120
Pb[1,5]	5-25	1,000-6,500	450
Zn[1,2]	30	135-7,210	100-280
Phosphorus	10-20		
Organics			
Benzene[7]	50[6]	9,200	
Chloroform[12]		23,900-36,500	
1,4-Dichlorobenzene[8]		1,120-1,200	11,000
Ethylbenzene[7]	1,400[6]	14,000	
Phenols	1		
Tetrachloroethylene[11,13]		13,400-20,300	17,700
Toluene[7,9]	500[6]	24,000	313
1,1,1-Trichloroethane[13]		42,300-52,900	
Trichloroethylene[10,13]		42,300-52,900	85,200
Xylene[7]	100[6]	8,200-13,500	

1 Environment Canada (1979-1980)
2 IJC (1977)
3 Eisler (1986)
4 IJC (1978)
5 IJC (1980)
6 Tentative PWQO values under consideration by MOE.
7 Mayer and Ellersieck (1986)
8 MOE (1984b)
9 EPA (1980b)
10 EPA (1978a)
11 EPA (1978b)
12 EPA (1980a)
13 Geiger et al. (1985). Data are for fathead minnows. The interspecies comparison between fatheads and rainbows developed by Thurston et al. (1985) indicates that the rainbow trout LC50's would be as much as two times higher. Therefore, the values cited here are conservative estimates.
14 MOE (1984a)

4.3.1 Metals

Representative rainbow trout and Daphnia 96-hour LC50 values for metals appear in Table 4.3, and were used to determine whether the concentrations measured in STP effluents may have contributed to observed toxicity.

Among all available Canadian sewage plant data, the only metals reported to exceed 0.2 of the representative LC50, whether or not the effluent was lethal, were copper, zinc and nickel (Appendix C, Tables C1 to C4). Their 0.2 times LC50 values were determined as 4, 20 and 102 ug/L, respectively. Nickel, elevated only in a few instances, was not associated with toxic effluents and is not, therefore, considered to be a common contributor to STP effluent toxicity.

Copper concentrations exceeded 4 ug/L in almost all samples from Galt, Waterloo and Welland STPs (Tables C1 to C3). Copper was also frequently elevated in Western Canadian STP effluents.

Of all STP effluents with measured metal concentrations, all but three of the lethal effluents from Canadian STPs contained greater than 10 mg/L ammonia and Cu, Zn or both were at levels above 0.2 of their respective LC50's (Table 4.4). In no case, where ammonia was less than 10 mg/L NH_3-N and copper above 4 ug/L, was the effluent lethal. Only one instance of lethality occurred when zinc was elevated (greater than 20 ug/L) and ammonia was low (NH_3 less than 10 mg/L). Copper and zinc, even when present below lethal concentrations, may augment ammonia toxicity in sewage effluents, but they are not likely primary causes of lethality for two reasons:

- o NH_3 occurs in some effluents at or above the documented LC50 levels, while Cu and Zn concentrations are usually only a fraction of their documented LC50; and
- o the occurrence of concentrations above 0.2 times the LC50 of Cu or Zn, in the absence of high ammonia, resulted in a lethal effluent in only one instance.

A survey of six Ohio activated sludge plants (Neiheisel et al. 1988) reported metal levels that rarely exceeded the LC50 values reported in Table 4.3. Copper and zinc were

TABLE 4.4: SUMMARY OF THE NUMBER OF LETHAL EFFLUENTS FROM CANADIAN SEWAGE PLANTS THAT CONTAIN TOXIC LEVELS* (mg/L) OF AMMONIA, COPPER AND/OR ZINC

			Lethal Effluents			Non-lethal Effluents			
Plant	No. Lethal Effluents	NH_3 GT 10**	NH_3 GT 10 + Cu or Zn GT 0.2 LC50	NH_3 L 10 + Cu GT 0.2 LC50	NH_3-N L 10 + Zn GT 0.2 LC50	NH_3 L 10 + Cu GT 0.2 LC50	NH_3 L 10 + Zn GT 0.2 LC50	NH_3 GT 10	NH_3 GT 10 + Cu or Zn GT 0.02 LC50
Prince George	0	0	0	0	0	2	2	2	2
Mission	0	0	0	0	0	0	0	8	8
Clinton	0	0	0	0	0	1	1	0	0
Williams Lake	0	0	0	0	0	4	2	0	0
Penticton	8	8	8	0	0	0	0	0	0
Iona Isle	4	4	4	0	0	0	0	0	0
Cache Creek	8	8	8	0	0	0	0	0	0
Annacis Isle	9	9	9	0	0	0	0	0	0
Lions Gate	1	1	1	0	0	0	0	0	0
Lulu Isle	3	3	3	0	0	0	0	0	0
Saskatoon PTP	2	2	2	0	0	0	0	0	0
Yorkton	1	1	1	0	0	0	0	0	0
North Battleford	1	1	1	0	0	0	0	0	0
Moosejaw	1	1	1	0	0	0	0	0	0
Winnipeg (North End)	3	3	3	0	0	0	0	0	0
Galt	2	2	2	0	0	0	0	0	0
Waterloo	0	0	0	0	0	13	13	0	0
Welland	4	1	1	0	1	5	4	1	1
TOTAL	47	44	44	0	1	25	22	26	26

* Based on concentrations exceeding 0.2 mg/L of the respective LC50s for rainbow trout or Daphnia.

** Total ammonia nitrogen GT 10 mg/L was determined to be a characteristic of lethal effluents.

L - less than.

GT - greater than.

occasionally elevated in STP effluents, but did not correlate with observed lethality among fathead minnows (Pimephales promelas). The toxicity of one STP effluent to the invertebrate, Ceriodaphnia sp., was however attributed to metals, particularly to zinc.

Additive or synergistic effects of copper, LAS (linear alkylbenzene sulfonate) and chloramines were reported by Tsai and McKee (1978). The interactions were dependent on rates of toxic action of the individual chemicals, toxicity ratios of the chemicals in the mixtures, and the concentrations of the mixtures. Statistical analyses were not performed to determine significant differences between LC50's of the mixtures, nor were contributions of each chemical quantified.

Copper was found in lethal concentrations (90 to 140 ug/L) at three STPs by Martens and Servizi (1976), but no significant concentration-lethality relationship was identified. Copper was the only metal of six measured by the EPA (1977) to reach potentially toxic levels in an STP effluent in Memphis, Tennessee. The effluent was lethal, but observed mortality was not related by the authors to specific effluent characteristics.

Canadian test results suggest that metals may contribute to toxicity in lethal sewage plant effluents. Clearly, further research is needed to clarify this issue.

4.3.2 Surfactants

Surfactants enter sewage plants in domestic and industrial wastewaters. Anionic surfactants are the most common type of surfactant, and usually arise from the use of detergents. They may vary in molecular chain length, and have a branched or linear structure (Abel, 1974). The Methylene Blue Active Substances (MBAS) method is often used to estimate the anionic surfactant content of water and wastewaters (APHA, 1985). Linear alkylbenzene sulfonates are the most widely used anionic surfactants, and are used to standardize the MBAS method.

The lethality of anionic surfactants increases as the number of carbon atoms increases and as the position of the phenyl moiety is located in a more terminal rather than a central position in the chain (Kimberle and Swisher, 1977). The toxicity of anionic surfactants can range over an order of magnitude depending on the molecular structure and organism tested. For example, the 96-hour LC50 to bluegill sunfish was 0.6 mg/L for

a linear (14-carbon chain) surfactant (Swisher et al., 1964 in Abel, 1974) compared to 17 mg/L for a branched surfactant (Cairns and Scheier, 1962 in Abel, 1974). Kimberle and Swisher (1977) measured LAS LC50's of 0.5 to 50 mg/L to Daphnia magna and fathead minnows. Since the MBAS method (APHA, 1985) measures the total of all anionic surfactant forms present, measured total surfactant concentrations will not necessarily correlate with measures of effluent lethality.

In a number of sewage plant effluent toxicity studies in British Columbia (Higgs, 1977a-g), surfactants were considered contributary components of effluent lethality on the strength of (MBAS) analyses. A study by Esvelt et al. (1973) demonstrated that treatment of sewage effluent by ion exchange resin or charcoal filtration reduced acute lethality. In that study, it appeared that reductions in surfactant concentrations decreased toxicity, but the authors did not attempt to identify what other toxicants may have been removed by sorption to the resin or filter. It was concluded that, on an equivalent mass basis, surfactants contributed almost six times more to the effluent toxicity than total ammonia. However, they also acknowledged that 74% of the lethality was unaccounted for and metals represented an obvious toxicant source that was not included in the relationship developed.

Quantitative assessment of surfactant contributions to sewage effluent lethality is circumstantial at best in the studies reported in the literature. The MBAS reaction responds to long chain carboxylsulphonates, inorganic ions and intermediate degradation products, as well as the many anionic surfactant homologs (Kimberle and Swisher, 1977). A tiered treatment-toxicity assessment of effluent lethality specifically focussing on surfactants separate from alternative potential toxicants may further elucidate the contribution of surfactants to effluent lethality.

4.3.3 Organic Compounds

In an evaluation of organic contaminants discharged by three selected Ontario sewage treatment plants. Parallel acute lethality tests were completed on influent and non-chlorinated effluent samples (Canviro, report in preparation). Organic compounds identified in samples lethal to rainbow trout and Daphnia magna are listed in Table 4.2 with representative 96-hour LC50 values. Concentrations 0.2 of the representative LC50 values were several orders of magnitude higher than measured concentrations in the

effluent (Appendix C, Tables C5 to C7), indicating that of the organics analyzed, none were significant contributors to the observed lethality. A possible exception was xylene which was greatly elevated (to 1,147 ug/L) in an influent sample from Galt which was lethal to Daphnia.

Other studies report very low concentrations (ug/L) of organics in STP effluents (Kopperman et al., 1976; EPA, 1977). Melcer (1986) concluded from a survey of treated effluents from 105 North American STPs that very low levels of U.S. EPA priority pollutants can be achieved in the effluents from well-operated secondary plants despite often high inflow levels. Primary plants were less able to remove the contaminants. Typically, between five and ten organic contaminants were found at concentrations ranging from 1 to 20 ug/L more than 50% of the time in effluents from well-operated secondary STPs. All reported concentrations were well below acutely toxic levels.

Neiheisel et al. (1988) conducted a survey of six Ohio activated sludge plants to test the acute and chronic toxicities of influent and effluent streams to fathead minnows (Pimephales promelas) and Ceriodaphnia sp. The concentrations of volatile organic pollutants detected in the effluents and even in the influents were not expected to have a major effect on the toxicity test organisms or receiving waters. The compounds measured were frequently below detection limits (0.2 to 2 ug/L) and 76% of the levels above detection remained less than 10 ug/L.

4.4 Summary

Ammonia toxicity has been demonstrated in laboratory tests of STP effluents in Ontario. Chlorine toxicity in effluents has been shown to be significant in continuous-flow tests in the laboratory, but conventional static bioassays allow dissipation of TRC and, therefore, result in inaccurate reflection of its toxic potency. At some STPs, other toxic components may be involved, such as metals, and may be related, in part, to the proportion of industrial inflow to the STP. Further tests coincident with reliable chemical assessments are required to clarify these points.

5.0 ENVIRONMENTAL FACTORS AFFECTING EFFLUENT TOXICITY

5.1 Seasonal Effects

From a review of the seasonal lethality of effluents at individual plants (Tables A1 and A2), it is evident that the majority of lethal STP effluents were produced during winter months. The study by Metikosh et al. (1980) provides the best examples, as each plant's effluent was evaluated for toxicity in both summer and winter. Ten of the 19 activated sludge plants sampled in Ontario demonstrated a higher percentage of acutely lethal samples in the winter months. A possible reason for this trend is that treatment system nitrification rates are reduced at lower temperatures, resulting in elevated ammonia levels. Eight of the remaining nine plants, however, were able to produce effluents which were consistently non-toxic in winter and summer. Metikosh et al. (1980) also tested the effluents from five lagoon STPs in Ontario (Table 5.1). In addition to reduced nitrification rates due to cold weather and ice cover, hydrogen sulphide (produced under anaerobic conditions) was implicated in winter effluent toxicity at lagoons. Only Listowel, with an aerated cell, produced consistently non-lethal effluents in winter. Further discussion of the effects of temperature on H_2S production and reduced nitrification is presented in Sections 7.3.2 to 7.3.4, where they are related to the processes and operating conditions of STPs.

Hydrogen sulphide is acutely lethal to rainbow trout at 8.7 ug/L and to goldfish at 80.4 ug/L. Invertebrate LC50's are reported from 20 to 1,070 ug/L (Smith et al., 1976). Metikosh et al. (1980) did not report the levels of H_2S measured in the effluents of Ontario lagoon STPs.

5.2 Receiving Water

5.2.1 Dilution Availability

Although an effluent may cause acute lethality in laboratory tests in undiluted samples, the natural receiving water will eventually dilute the effluent to non-lethal levels. However, where small watercourses which are subject to large changes in seasonal flow act as the receiving environment for effluent discharges, there may be periods where insufficient dilution volume is available to make effluents non-toxic. In these situations

TABLE 5.1: COMPARISON LETHALITY OF EFFLUENTS FROM FIVE LAGOON TREATMENT SYSTEMS IN ONTARIO DURING SUMMER AND WINTER

STP	Percent Lethal Samples (n)	
	Summer	Winter
Listowel (aerated, continuous discharge)	0% (10)	0% (8)
Markdale (non-aerated, continuous discharge)	0% (9)	70% (10)
Wingham (non-aerated, continuous discharge)	0% (10)	55% (11)
Mitchell (non-aerated, seasonal discharge)		40% (5)
Tavistock (non-aerated, seasonal discharge)		60% (5)

and when empirical information on the actual receiving site is unavailable, it is important to use some estimate of the degree of dilution that is required before non-toxic conditions can be met.

The maximum and mean flows of Ontario STPs characterized by effluent toxicity data with the maximum, mean and minimum flows of their respective receiving waters are presented in Table 5.2. The dilution ratios for mean flows without considering low flow conditions ranges from 6.5:1 to 2400:1 for these plants. This clearly suggests that there are other plants that may be severely limited in available dilution, and produce toxic effects in the near- and far-field mixing zones.

In recognition that ammonia is a major contributor to effluent toxicity, it is useful to review the frequency distribution of total ammonia nitrogen concentrations reported from Canadian plants (Tables 4.1a and 4.1b). The maximum total NH_3 concentration reported in the data set prepared for this study is 37 mg/L. Considering that the lethal threshold for total ammonia has been estimated as 10 mg/L, it is logical that a 4:1 dilution (37/10 = 3.7) or greater would be required to avoid lethal effects in receiving environments. Increases in ambient temperature and pH would result in greater dilution requirements due to exponential elevation of un-ionized ammonia. The latest IJC (1986) Great Lakes Water Quality Objective of 0.03 mg/L un-ionized ammonia that should not be exceeded to protect against chronic toxicity would be represented by 1.5 mg/L total ammonia under standard testing conditions (pH 7.8; 15°C) and, as such, would require 25:1 dilution (37/1.5) or greater.

Total chlorine residual is the other major contributor to effluent toxicity and, as identified in Section 4.2.6, the effluent target concentration in Ontario is 0.5 mg/L. Brief review of the toxicity literature indicated that concentrations of 0.04 and 0.01 mg/L TRC represented the thresholds for acute and chronic toxicity for aquatic organisms. Dilution envelopes which would circumscribe the potential lethal and sublethal effect zones would be contained within the 12.5:1 and 50:1 mixing zones, respectively.

The more stringent dilution requirements of TRC may well provide the additional protection necessary to allow for fluctuations of un-ionized ammonia concentrations. The acute lethal dilution ratio of 12.5:1 and the sublethal dilution ratio of 50:1 may

TABLE 5.2: RECEIVING WATER DILUTION RATIOS FOR SELECTED SECONDARY STP EFFLUENTS IN ONTARIO

STP	Receiving	Receiving Water (m^3x10^3/d) Minimum Discharge	Maximum Discharge	Mean Discharge	STP[1] (m^3x10^3/d) Maximum Discharge	Mean Discharge	STP Effluent Dilution Minimum Min. Rec./Max. STP	Maximum[3] Max. Rec./Mean STP	Mean Mean Rec./Mean STP
Brantford	Grand River	1,600	58,500	4,670	58.6	44.2	27.3	1,320	106
Burlington Skyway	Hamilton Harbour[2]	N/A	N/A	N/A	115	66.7	100	100	100
Clarkson	Lake Ontario[2]	N/A	N/A	N/A	134	56.3	100	100	100
Galt	Grand River	1,160	36,700	2,870	47.2	30.0	24.5	1,220	95.5
Grand Valley	Grand River	29.8	12,500	605	137	0.252	21.8	49,700	2,400
Guelph	Speed River	134	4,260	479	115*	47.7	1.2	89.3	10.0
Hamilton	Hamilton Harbour[2]	N/A	N/A	N/A	590*	308	100	100	100
Hespeler	Speed River	134	4,260	479	9.55	5.39	14.0	790	88.8
Ingersoll (old)	Thames River	101	4,770	454	3.45	633	29.3	3,590	342
Ingersoll (new)	Thames River	101	4,770	454	6.41	3.30	15.8	1,440	138
Kitchener	Grand River	1,160	36,700	2,870	109	59.7	10.6	615	48
Lakeview	Lake Ontario[2]	N/A	N/A	N/A	315	170	100	100	100
Orangeville	Credit River	17.2	484	51.0	21.4	6.72	0.81	72	7.6
Preston	Grand River	1,160	36,700	2,870	137	7.79	84.3	4,720	368
St. Jacobs	Conestoga River	39.7	3,720	490	4.34	1.11	9.1	3,350	441
Stratford	Avon River	11.8	3,905	133	60.0	20.5	0.20	190	6.5
Tillsonburg	Big Otter Creek	70.3	4,220	34.7	7.20	4.61	9.8	914	75.3
Waterdown	Grindstone Creek	5.36	1,410	51.5	11.2*	2.22	0.45	635	23.2
Waterloo	Grand River	1,160	36,700	2,870	61.8	33.2	18.7	1,110	86.4
Welland	Welland River	10,400	22,600	19,300	128*	35.8	81.2	631	539

[1] Based on 1981 STP data as that was most recent year for which receiving water discharges were also available.
* Indicates STP discharge data are from 1985.

[2] Receiving water is a lake; therefore, 100:1 dilution is assumed.

[3] Based on mean STP discharge due to unavailability of minimum values.

N/A - not applicable.

indeed appear to represent useful guidelines for determining the adequacy of available dilution in receiving streams and estimating the extent of impact in receiving waters.

5.2.2 Receiving Water Quality Effects on Toxicity

It is well known that water quality characteristics such as pH, temperature, alkalinity, etc. can affect the environmental behaviour and the toxicity of some contaminants to aquatic organisms. With respect to STPs, the factors which alter ammonia and chlorine toxicity are of particular concern.

Receiving water quality characteristics probably do not have a major effect on chlorine-induced toxicity. The greatest interaction of chlorine would likely be with ammonia, to form chloramines, and would occur in the effluent prior to release into the receiving water. Little chlorine will likely exist in the free form (Brungs, 1973). As discussed in Section 4.2, chloramines are slightly less toxic than free chlorine, but are more persistent.

Brooks and Seegert (1978) suggested that temperature differences have little effect on chlorine toxicity at low temperatures, but cause increased sensitivity at higher temperatures, the range of temperatures being species-dependent. They also reported that, although pH affects the speciation of chlorine, pH effects on TRC toxicity have not been clearly established. It is possible that low pH may increase toxicity due to the resulting increase in free chlorine (Brungs, 1973).

Fe(II), sulphide and easily oxidized organic compounds probably cause the initial rapid reduction of aqueous chlorine residual in water. Sunlight, copper, bromide or other redox catalysts may also increase TRC dissipation (Johnson, 1976).

Ammonia toxicity is affected by receiving water pH and temperature which alter the proportion of ammonia existing in the toxic un-ionized form. The equation in Section 4.1 shows how the fraction of un-ionized ammonia varies directly with increased pH and temperature. Table 5.3 identifies a range of receiving water pH, temperature and the respective total ammonia concentration above which will result in lethality (i.e., un-ionized ammonia will exceed 0.17 mg/L).

TABLE 5.3: LEVELS OF TOTAL AMMONIA NITROGEN (mg/L) IN EFFLUENT NOT TO BE EXCEEDED FOR THE PROTECTION OF AQUATIC BIOTA

Receiving Water pH	6.6	6.8	7.0	7.2	7.4	7.6	7.8	8.0	8.2	8.4	8.6	8.8	9.0
Un-ionized NH_3 (mg/L)	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Temperature (°C)				Equivalent Values of Total Ammonia as Nitrogen (mg/L)									
1	398	251	158	100	63	40	25	126	10	6	4	3	2
2	366	231	146	92	58	37	23	15	9	6	4	2	2
3	337	213	134	85	54	34	21	14	9	5	4	2	1
4	310	196	124	78	49	31	20	12	8	5	3	2	1
5	286	181	114	72	45	29	18	12	7	5	3	2	1
6	264	167	105	66	42	27	17	11	7	4	3	2	1
7	243	154	97	61	39	24	15	10	6	4	3	2	1
8	225	142	90	57	36	23	14	9	6	4	2	2	1
9	208	131	83	52	33	21	13	8	5	3	2	1	1
10	192	121	76	48	31	19	12	8	5	3	2	1	1
11	177	112	71	45	28	18	11	7	5	3	2	1	1
12	164	104	65	41	26	17	10	7	4	3	2	1	1
13	152	96	61	38	24	15	10	6	4	3	2	1	1
14	141	89	56	35	22	14	9	6	4	2	2	1	1
15	131	82	52	33	21	13	8	5	3	2	1	1	1
16	121	76	48	31	19	12	8	5	3	2	1	1	1
17	112	71	45	28	18	11	7	5	3	2	1	1	1
18	104	66	42	26	17	11	7	4	3	2	1	1	1
19	97	61	39	24	15	10	6	4	3	2	1	1	1
20	90	57	36	23	14	9	6	4	2	2	1	1	0
21	84	53	33	21	13	8	5	3	2	1	1	1	0
22	78	49	31	20	12	8	5	3	2	1	1	1	0
23	72	46	29	18	12	7	5	3	2	1	1	1	0
24	67	43	27	17	11	7	4	3	2	1	1	1	0
25	63	40	25	16	10	6	4	3	2	1	1	1	0
26	59	37	23	15	9	6	4	2	2	1	1	1	0
27	55	35	22	14	9	6	4	2	2	1	1	0	0
28	51	32	20	13	8	5	3	2	1	1	1	0	0
29	48	30	19	12	8	5	3	2	2	2	2	0	0
30	44	28	18	11	7	5	3	2	1	1	2	0	0

5.3 Summary

The data reviewed suggest that Ontario STPs tend to produce toxic effluents more frequently in the winter months. This is probably as a result of reduced nitrification rates during low temperature operation.

The amount of receiving water dilution available for an effluent will determine the downstream area where toxic effects will be observed. Estimated instantaneous dilution factors for several Ontario STPs suggests that there are undoubtedly some plants which will generate substantial toxic impact zones. The physical and chemical characteristics of each receiving water body may also affect the toxicity of various components of the effluents, as well as their persistence.

6.0 PREDICTION OF FIELD IMPACT FROM LAB TOXICITY TESTS

6.1 Reliability of Toxicity Tests to Predict Receiving Water Impact

The toxicity test is a biological tool used to quantify the cumulative effect of toxic contaminants in an effluent. By measuring the response of organisms to an effluent, a more comprehensive assessment of receiving water impact can be determined than measurement of selected chemicals for which documented toxicity may or may not exist. Following the previous discussion of toxicity testing, it is instructive to review the role of such tests with respect to the MISA program. Evidence of the usefulness of laboratory tests to predict field impacts is not abundant, but some studies have been conducted to demonstrate the predictive reliability of toxicity tests.

The U.S. EPA, through its National Pollutant Discharge Elimination System (NPDES) program, has also recognized the need for biological monitoring. Recently, the Complex Effluent Toxicity Testing Program was undertaken to support the developing trend toward water quality-based toxicity control in the NPDES permit program. The purpose of these studies was to determine the capability of chronic toxicity tests to predict field impacts. While acute toxicity tests were not conducted, review of the results and conclusions of the EPA studies lends support to the concept of routine biological testing in effluent monitoring.

The U.S. EPA completed laboratory toxicity tests on industrial and sewage treatment plant effluents discharging to four rivers in Alabama, Connecticut, Ohio and Oklahoma during the summers of 1982, 1983 and 1984. In all studies, laboratory tests were compared with field evaluations of benthic diversity and abundance, fish community taxa and zooplankton abundance downstream of the discharges. The tests conducted included the seven-day fathead minnow (Pimephales promelas) larval survival and growth test, and the water flea (Ceriodaphnia reticulata) survival and reproduction test. Table 6.1 outlines the relationships identified between the laboratory tests and field impacts.

A similar type of study was conducted by the EPA in Akron, Ohio to provide NPDES program managers, NPDES permit writers and water quality specialists with an example of how toxicity testing can be used to address pre-identified toxic water quality problems (EPA, 1987). The Akron Publicly Owned Treatment Works (Akron POTW) discharges its

TABLE 6.1: EPA STUDIES OF THE RELATIONSHIP BETWEEN LABORATORY TOXICITY TESTS AND RECEIVING WATER IMPACT

Study Site	Fathead Minnow Test	Ceriodaphnia Test
Birmingham, Alabama Five Mile Creek (EPA, 1985)	No lethal or sublethal effects observed in lab tests. No significant field impact from POTW compared to immediate upstream station conditions. Confounding influences from upstream coke plant effluents. Generally, good agreement between toxicity test results and field biological community response throughout river system, but not on a station-to-station basis.	
Waterbury, Conn. Naugatuck River (EPA, 1986a)	Toxic slug from POTW produced 47% mortality. Correlations with field data not completed	Toxic slug from POTW produced 100% mortality. Significant negative correlation between daphnid sublethal toxicity and periphyton, macroinvertebrate and fish richness.
Lima, Ohio Ottawa River (EPA, 1984)	POTW produced no lethal or sublethal effects.	POTW lethal to daphnids and inhibited reproduction. Reproductive impairment negatively correlated with benthic diversity and abundance. No correlation between fecundity and fish community.
Enid, Oklahoma Skeleton Creek (EPA, 1986b)	POTW effluent not tested with either system since it was pumped to a refinery and fertilizer plant as process water by night and to the river by day. Both fathead and daphnid sublethal toxicity results were significantly correlated with reductions in zooplankton, macroinvertebrate and fish taxa density.	

effluent into the Cuyahoga River. It is a secondary treatment facility for 2.2 to 4.4 m^3/s of industrial and domestic waste. At certain times during the year, the wastewater comprises up to 60% of the total flow of the river. Although the physical habitat of the river indicates the potential for supporting an excellent warmwater fishery, a highly impacted zone was identified several years ago below the Akron POTW. The EPA study demonstrated water quality based toxicity control procedures can be combined with chemical analyses and biological stream surveys to achieve more effective water pollution control. Toxicity tests conducted with Ceriodaphnia, the snail Aplexia and fathead minnows indicated that effluent toxicity varied with time, and that Ceriodaphnia were more sensitive than the snails and larval fish. Ceriodaphnia demonstrated impaired reproduction at an effluent concentration as low as 30%.

After calculating the dilution provided by the Cuyahoga River, it was determined that a toxic impact would indeed be expected from the POTW discharge. Observed impairment of fish and invertebrate community health confirmed the toxicity test predictions of substantial effluent impact.

The above studies identified that sublethal tests consistently detected toxic effluents. Furthermore, because of the differences in sensitivity between the two representative organisms, depending on the type, number and proportionate concentrations of the toxicants, both fish and invertebrate test organisms were required to reliably detect toxic conditions. The authors of the EPA reports state that the greater variety of test organisms used representing the impacted biological community, the greater the reliability in predicting impact. In other words, investigators should not feel limited to using only fathead minnows and Ceriodaphnia to estimate effluent effects on receiving water. Finally, the above reports demonstrate that generally the two test systems do correlate well with observed biological community effects. Where effluent toxicity can be demonstrated, it is possible to identify some degree of biological impairment in receiving water systems.

Similar studies are currently underway at three Ontario STPs for pilot studies of the MOE MISA program.

6.2 Summary

Biological tests of treatment plant effluents can reliably predict whether the receiving waters are affected by the discharge. Acute and chronic tests with a variety of representative receiving water species provide a good estimation of field effects.

7.0 CATEGORIZATION OF ONTARIO STPs BY TREATMENT PROCESS CHARACTERISTICS

7.1 Criteria for Categorization

Three criteria were established to categorize Ontario treatment plants with respect to effluent toxicity field monitoring. Available toxicity data could then be used to further define priority for the categories. The data would not only indicate which categories of effluents are toxic or non-toxic, but which categories are lacking in information, and hence requiring additional monitoring data. The three criteria for categorization of STPs were:

- o treatment process class,
- o treatment process operating efficiency, and
- o fraction of industrial flow contribution to total plant flow.

Treatment process class is an important factor which affects the quality of the effluent discharged by a STP. The three process categories evaluated in this study are primary plants, secondary plants and lagoons. Both primary and secondary treatment plants are mechanical facilities, but the effluent quality produced differs substantially. Primary plants are designed principally to reduce particulate contaminants, while secondary facilities reduce both particulate and soluble contaminant concentrations. Lagoons are non-mechanical plants capable of reducing concentrations of soluble and particulate contaminants.

Operating efficiency was established as the second criterion to relate effluent toxicity to the quality of the wastewater discharged from a treatment plant. Operating data used to evaluate treatment efficiency were BOD_5 removal and effluent total ammonia-N concentration. Efficiently operating plants were those with BOD_5 removals of 80% or higher, and effluent total ammonia-N concentrations of less than 10 mg/L. Plants with poor operating efficiency were those in which the BOD_5 removal efficiency was less than 80% and the effluent total ammonia-N concentration was 10 mg/L or greater. Treatment plants in which one of the two operating criteria was not achieved were classified separately. This criterion was generally applicable only to secondary plants and lagoons. Primary plants would almost always produce a poor quality effluent by this criterion.

The third criterion was established to estimate the impact of industrial contaminants on STP effluent toxicity. The basis for this criterion was the assumption that higher concentrations of hazardous contaminants from industrial sources will result in greater toxicity. There is a scarcity of actual industrial effluent toxicity monitoring data to confirm this assumption, but the premise is consistent with the acute toxicity test for determining the LC50 value. Three categories of industrial contribution to a treatment plant, based on flow, were established. These included domestic wastewater only (less than 5% industrial flow), minor industrial input (between 5 and 30% industrial flow), and major industrial flow (greater than 30% industrial flow). This categorization is consistent with the toxicity study reported by Metikosh et al. (1980).

Methodology

Treatment plants were classified by process according to descriptions contained in the 1985 Operating Summary of Wastewater Treatment Facilities in Ontario prepared by the Ontario Ministry of the Environment (1987).

The MOE's computerized Utility Monitoring Information System (UMIS) and Total Utility and Municipal Monitoring Information System (TUMMIS) databases were used to classify pollution control plants according to whether effluent ammonia concentrations exceeded or were less than 10 mg/L on a monthly basis. Data from 1986 were utilized for the classification. For continuously discharging STPs (i.e., both mechanical plants and lagoons), only those plants with seven months or more of effluent ammonia levels in the year were evaluated. If less than 12 months of data were available for these STPs, the frequency of effluent ammonia concentrations exceeding 10 mg/L was established by pro-rating the number of months of available data to an equivalent annual basis. In the case of seasonally or annually discharging lagoons, the number of months of available data were pro-rated to an equivalent annual basis, regardless of the number of months of data. This procedure served to bring the treatment plants to a common basis for evaluation by establishing the percentage number of months each year that any STP exceeded 10 mg/L NH_3-N. The classification of the Ontario STPs by monthly ammonia data appears in the back of the report as Appendix D.

For the STPs for which monthly ammonia data were not available, annual averages of effluent ammonia (1985) were retrieved from the UMIS and TUMMIS databases.

Treatment plants falling into this group were classified as having effluent ammonia levels exceeding or less than 10 mg/L. The plants are categorized in Appendix E.

BOD_5 removal efficiency was calculated for each facililty using average annual influent and effluent BOD_5 concentrations reported in the 1985 operating summary (MOE, 1987).

Estimates of industrial flow contribution to the total plant flow were noted from existing surveys of pollution control plants by Canviro Consultants where possible. If industrial contributions to the pollution control plants were not available from these sources, then the industrial flow to primary and secondary treatment plants was calculated based on a computerized procedure (HAZPRED) developed by CANVIRO for estimating trace contaminant concentrations in sewers (CANVIRO, 1984). The average daily flow and population served by a STP were first noted from the 1985 operating summary (MOE, 1987). The flow contribution from residential sources was then calculated based on a per capita consumption/discharge rate of 220 L/d (CANVIRO, 1984). The rate of wastewater production from commercial establishments was based on discharge rates reported by CANVIRO using their HAZPRED model in two Toronto sewersheds, and by data reported by Brandes (1978) for water consumption by individuals for sanitary purposes only. The commercial rate of water discharged to sewers was estimated at 30 L/cap'd.

Infiltration and inflow (I/I) contribute to the total flow of a sewer at rates which are dependent on a number of factors including age of system, type of system (clay, cast iron, PVC, etc.), watertable depth, cross-connections with storm sewers and type of soil matrix in which the pipe is laid. An estimate of the range of I/I rates to sewers, based on connected population, is 91 to 227 L/capd (CANVIRO, 1984). For this study, an average value of 150 L/cap'd was assumed in the absence of detailed I/I data for each plant. This assumption may result in low or high estimates of the I/I component in some cases, but it is believed on average that this would be a "typical" figure.

The industrial component of the total wastewater flow arriving at a primary or secondary treatment plant was then calculated as the difference between the total flow reported by the 1985 operating summary (MOE, 1987) and the summed residential, commercial and I/I components.

Although the HAZPRED method adapted for this study provided a good basis for classifying primary and secondary plants according to industrial contribution, the

methodology, which uses per capita flow estimates, was not considered as accurate for lagoons. The procedure resulted in a heavy bias to the major industrial flow component. Discussions with MOE regional officials and checking with municipal industrial trade directories confirmed that the method was substantially overestimating the industrial flow component on a frequent basis.

Because of the lack of data on industrial flow contributions to Ontario STPs, the categorization of lagoons by industrial component was carried out using wastewater strength as the determining criterion. Annual influent BOD_5 concentrations, as reported in the 1985 Operating Summary (MOE, 1987), were used to measure wastewater strength, and hence industrial contribution. The industrial flow categories established for lagoons were as follows:

- o BOD_5 less than 125 mg/L: Domestic only
- o BOD_5 between 125 and 250 mg/L: Minor industrial
- o BOD_5 greater than 250 mg/L: Major industrial

These categories are similar to classifications of municipal wastewater strength reported by Metcalf and Eddy (1972). BOD_5 concentrations in raw wastewater could be diluted by I/I, with the effect that STPs which should be classified as major industrial could be grouped under minor industrial, or even domestic, depending on the magnitude of the I/I problem. Although this procedure does not allow the BOD_5 concentrations to be corrected for an I/I, the category limits were selected based on the knowledge that I/I would have some impact on the classification.

Because of missing data in the electronic databases used for categorization, additional data were retrieved where possible by telephone to municipal or Ministry officials. When this approach failed, assumptions were applied to provide additional plants for categorization. When ammonia data were missing, lagoons and secondary plants were assumed to produce effluents with ammonia levels of less than 10 mg/L. This is consistent with the majority of the plants with reported effluent ammonia data. Communal septic tanks were assumed to have effluent ammonia levels greater than 10 mg/L when those data were missing.

When effluent BOD_5 data were missing such that no BOD_5 removal efficiency could be calculated (influent data were available), it was assumed for lagoons that removal

efficiencies were greater than 80%, again consistent with the majority of the data with recorded values. If lagoons did not discharge for the operating year, yet received a daily flow, it was assumed that the long retention time provided would also produce low effluent BOD_5 concentrations, and hence removal efficiencies greater than 80%, when discharged.

A small number of treatment plants (mainly communal septic tanks and exfiltration lagoons) had no recorded daily flows. In this case, the average daily flow was estimated by multiplying the population served by a per capita discharge of 220 L/d. If more than one assumption was required to classify an STP, then the plant was categorized as having insufficient data for classification.

The procedure based on the HAZPRED methodology used for calculating the industrial component was found to be biased towards estimating major industrial flow components. This bias is believed to be due to apparently excessive infiltration/inflow to the collection system. Because only a portion of this flow is attributed by the algorithm to infiltration, the remainder is classified as industrial flow. The persistent high water levels in 1985 and 1986 resulted in a substantial infiltration and inflow, especially for treatment plants situated close to the Great Lakes, according to the STP superintendents. Consequently, a number of treatment plants were re-assigned from major industrial to minor industrial or domestic flow based on the concentrations of conventional parameters in the raw wastewater, conversation with MOE and municipal officials, and on professional judgement.

Use of the sewage treatment plants categorized by industrial flow component outside of this report should be done cautiously, since assumptions have been made with respect to estimation of commercial, industrial and infiltration/inflow components of the total flow or to contributions to BOD_5 loadings. For accurate assessment of these individual flow components, municipal water consumption records, industrial wastewater discharge records, and I/I studies at municipal STPs should be utilized.

7.2 Categorization of Ontario STPs

Monthly Ammonia Data

The classification procedure using monthly effluent ammonia concentrations resulted in the matrix shown in Table 7.1. The majority of treatment plants, both lagoons and secondary plants, were grouped as producing effluents in which ammonia levels never exceeded 10 mg/L during the year. Of the 180 STPs for which monthly NH_3 records were examined, 109 (nearly 61%) never exceeded effluent ammonia levels of 10 mg/L during the year. Annual BOD_5 removal efficiencies in lagoons and secondary plants were most often greater than 80%; in primary plants, BOD removal efficiencies in the plants evaluated never exceeded 80%. The industrial components of lagoons were, in general, rated as either domestic or minor industrial. Most primary plants were classified as treating domestic wastewater. The secondary plants were nearly equally represented by wastewaters classified as domestic, minor industrial or major industrial. In all, a total of 180 Ontario STPs were evaluated using this procedure. The complete listing of the treatment plants appears as Appendix D.

Annual Ammonia Data

For treatment plants that were evaluated using annual effluent ammonia concentrations, a similar picture is presented. This evaluation produced the matrix shown in Table 7.2. Most lagoons and secondary treatment facilities were classified as producing effluents with annual average ammonia concentrations less than 10 mg/L and BOD removal efficiency greater than 80%. Most primary treatment plants had annual ammonia concentrations greater than 10 mg/L, while BOD removal efficiency was less than 80%. Of the plants evaluated using these criteria, most were regarded as treating domestic wastewater rather than wastewater with minor or major industrial contributions, regardless of process type.

The complete listing of treatment plants evaluated using annual effluent ammonia concentrations appears as Appendix E. A total of 24 plants were listed as having insufficient data for any form of evaluation. The locations of all 401 treatment plants in Ontario are noted by process type and receiving water on maps contained in Appendix F.

TABLE 7.1: MATRIX OF ONTARIO TREATMENT PLANTS ACCORDING TO PROCESS OPERATING CRITERIA (MONTHLY EFFLUENT AMMONIA CONCENTRATIONS)

		INDUSTRIAL COMPONENT							
	Months/Year	Domestic		Minor		Major		Total	
Type of	Effluent	BOD Removal		BOD Removal		BOD Removal		BOD Removal	
Plant	NH_3* GT 10 mg/L	L 80%	GT 80%	L 80%	GT 80%	L 80%	GT 80%	L 80%	GT 80%
Lagoons	0	9	26	1	22	0	5	10	53
	1-3	1	5	0	6	0	0	1	11
	4-6	2	4	1	1	1	3	4	8
	7-9	0	0	0	0	0	0	0	0
	10-12	1	0	0	0	0	0	1	0
Primary	0	1	0	0	0	0	0	1	0
	1-3	0	0	0	0	0	0	0	0
	4-6	1	0	0	0	2	0	3	0
	7-9	1	0	0	0	0	0	1	0
	10-12	1	0	0	0	0	0	1	0
Secondary	0	2	14	1	19	0	9	3	42
	1-3	1	1	0	8	0	9	1	18
	4-6	0	2	2	4	1	1	3	7
	7-9	0	2	0	1	0	3	0	6
	10-12	0	2	0	1	0	3	0	6
TOTAL	0	12	40	2	41	0	14	14	95
	1-3	2	6	0	14	0	9	2	29
	4-6	3	6	3	5	4	4	10	15
	7-9	1	2	0	1	0	3	1	6
	10-12	2	2	0	1	0	3	2	6

* NH_3 - total ammonia nitrogen.
L - less than.
GT - greater than.

TABLE 7.2: MATRIX OF ONTARIO TREATMENT PLANTS ACCORDING TO PROCESS OPERATING CRITERIA (ANNUAL EFFLUENT AMMONIA CONCENTRATIONS)

		Effluent Total NH_3-N Concentration			
		Less than 10 mg/L		Greater than 10 mg/L	
Process	Industrial Flow Component	BOD Removal Less Than 80%	Efficiency 80% or Greater	BOD Removal Less Than 80%	Efficiency 80% or Greater
Lagoons	Domestic	6	19	1	1
	Minor	0	15	0	0
	Major	1	4	0	2
Secondary	Domestic	8	62	2	2
	Minor	2	25	0	2
	Major	0	19	0	0
Primary	Domestic	6	0	11	1
	Minor	2	0	3	0
	Major	2	0	3	1

Insufficient Data = Lagoons 14
Secondary 3
Primary 7

7.3 Toxicity Associated with Process Classes

7.3.1 Primary Plants

The study of toxicity of Ontario STP effluents by Metikosh et al. (1980) was the principal source used to evaluate the effects of process class and operating efficiency on effluent toxicity. The study examined acute toxicity, using rainbow trout, of secondary effluents, primary effluents at secondary plants, and a limited number of lagoon effluents. It should be noted that this study is nearly ten years old, and the effluent toxicity of the STPs may have changed in that interval of time.

The primary effluents tested for acute toxicity were collected between 03 January and 13 February 1978. Pertinent operating and chemical data for primary clarification at these plants are reported in Table 7.3. Two points with respect to these data should be noted which affect the categorization of the plants by process operating efficiency. First, BOD_5 removal efficiency never exceeded the criterion value of 80%, which was established principally for secondary plants and lagoons. In Table 7.3, a number of negative BOD_5 removal efficiencies were noted, which are probably a result of collecting a limited number of grab samples which may not represent the process operation as well as 24-h composite samples. Secondly, the mean total ammonia-N concentration in all primary effluents always exceeded the criterion value of 10 mg/L, which was reported earlier to be the critical concentration above which acute toxicity became readily observed (Section 4.1). This observation is also consistent with primary treatment, which is not designed to remove soluble components such as total ammonia-N.

For primary effluents, the grouping of treatment plants by industrial contribution and process operating efficiency are reported in Table 7.4. As noted above, all primary effluents were included in the operating efficiency category of BOD_5 removal less than 80% and total ammonia-N concentration greater than 10 mg/L. The study by Metikosh et al. (1980) clearly investigated treatment plants with a major industrial flow component. In all the primary effluent samples collected, 100% mortality of the fish was observed within 24 hours.

Toxicity testing of STP effluents in British Columbia by Higgs (1977a, c) have resulted in similar observations. At the Annacis Island and Iona Island primary treatment plants,

TABLE 7.3: SUMMARY OF PROCESS DATA FOR PRIMARY SEDIMENTATION AT SELECTED ONTARIO STPs (after Metikosh et al., 1980)

Treatment Plant	BOD_5 Removal Efficiency (%)	Total NH_3-N Concentration (mg/L)	Industrial Flow Component*
Brantford	-23	12.1	major
Burlington, Drury Lane	15	11.7	major
Burlington Skyway	-19	15.7	major
Clarkson	1	16.3	minor
Galt	8	13.0	major
Guelph 1	26	13.2	major
Guelph 2	7	15.6	major
Hamilton	8	23.1	major
Ingersoll 1	-5	17.5	major
Ingersoll 2	-11	17.0	major
Kitchener 1	46	26.8	major
Kitchener 2	36	23.0	major
Lakeview 1	35	26.0	major
Lakeview 2	32	29.5	major
Lakeview 3	31	19.3	major
Orangeville	23	21.0	minor
Preston	33	20.5	major
Stratford	1	13.6	major
Tillsonburg	7	22.0	major
Waterdown	-6	16.8	domestic
Waterloo	19	21.2	major

* As estimated by Metikosh et al. (1980).

TABLE 7.4: CATEGORIZATION AND TOXICITY OF PRIMARY EFFLUENTS BASED ON PROCESS EFFICIENCY AND INDUSTRIAL FLOW CONTRIBUTION (after Metikosh et al., 1980)

Total NH_3-N Concentration (mg/L)	BOD_5 Removal Efficiency (%)	Industrial Flow Componment*: Domestic	Minor	Major
> 10	> 80			
	< 80	Waterdown	Orangeville	Brantford
			Clarkson	Burlington Drury Lane
			Annacis Island**	Burlington Skyway
				Galt
				Guelph 1
				Guelph 2
				Hamilton
				Ingersoll 1
				Ingersoll 2
				Kitchener 1
				Kitchener 2
				Lakeview 1
				Lakeview 2
				Lakeview 3
				Preston
				Stratford
				Tillsonburg
				Waterloo
< 10	> 80			
	< 80			Iona Island**

* 50% or more of samples from all STPs were acutely toxic to rainbow trout (100% mortality in 24 hours).

** British Columbia data from Higgs (1977c).

BOD_5 removal efficiencies were 30% and 27%, respectively. Total ammonia-N concentrations in the effluents were 24.1 mg/L at Annacis Island and 9.35 mg/L at Iona Island.

The actual contribution of industrial flow to these plants is not available. Application of the HAZPRED methodology established for this study resulted in categorization of the Iona Island plant as having major industrial input, and the Annacis Island plant as receiving domestic wastewater only. The latter plant receives industrial wastewater discharged by pulp and paper mills, lumber processors, metal fabricators and metal finishers, food processors, and petroleum and petrochemical plants. The influent BOD_5 of the Annacis Island plant is also almost 25% higher than the BOD_5 of Iona Island sewage. Consequently, the industrial component of the flow to Annacis Island has been rated as minor for this investigation.

All four samples of Annacis Island effluent caused 100% mortality in the test fish within 24 hours, while three of four samples of Iona Island effluent caused 100% mortality in 24 hours. These data have been included with the Ontario data in Table 7.4.

Because almost all of the primary effluents tested were treatment plants receiving a major industrial input, the effect of industrial contribution cannot be assessed from these data. The effect of process efficiency on primary effluent toxicity similarly cannot be stated definitively because none of the primary effluents had total ammonia-N concentrations less than 10 mg/L (except for Iona Island) or BOD_5 removal efficiencies greater than 80%. It is clear, however, that a poor quality effluent, as produced by primary treatment alone, is acutely lethal to the test organism (rainbow trout).

7.3.2 Secondary Plants

The report by Metikosh et al. (1980) was the principal source of data for evaluating the impact of process efficiency on the toxicity of secondary effluents. The toxicity testing program for that study was conducted in two phases to provide data representing both summer and winter operating conditions. The summer program lasted from 22 August to 24 October 1977, and the winter program from 03 January to 13 February 1978. Operating data for these two periods are reported in Table 7.5.

TABLE 7.5: OPERATIONAL DATA FOR SECONDARY TREATMENT PLANTS EVALUATED IN TOXICITY STUDY (after Metikosh et al., 1980)

Treatment Plant	Industrial Flow Input	Summer			Winter		
		BOD_5 Removal Efficiency (%)	Effluent Total NH_3-N Concentration (mg/L)	F/M+ (day^{-1})	BOD_5 Removal Efficiency (%)	Effluent Total NH_3-N Concentration (mg/L)	F/M (day^{-1})
Brantford	major	95	0.5	0.10	91	10.0	0.10
Burlington Drury Lane	major	97	0.6	0.08	97	0.8	0.10
Burlington Skyway	major	96	9.2	0.14	94	2.2	0.11
Clarkson	minor	96	0.2	0.02	95	0.34	0.01
Galt	major	90	2.4	0.11	93	10.0	0.11
Grand Valley	domestic	97	1.2	0.04	96	26.0	0.02
Guelph 1	major	88	10.6	0.12	94	12.0	0.18
Guelph 2	major	96	7.8	0.14	93	16.0	0.19
Hamilton	major	95	9.7	0.16	91	14.4	0.25
Hespeler	major	87	8.2	0.33	92	12.3	0.57
Ingersoll 1	major	97	0.3	0.03	98	0.5	0.03
Ingersoll 2	major	96	0.9	0.20	95	5.0	0.14
Kitchener 1	major	95	0.3	0.04	98	7.5	0.08
Kitchener 2	major	91	1.2	0.03	96	9.4	0.05
Lakeview 1	major	96	5.1	0.11	98	1.4	0.17
Lakeview 2	major	97	7.7	0.21	99	13.0	0.44
Lakeview 3	major	96	2.6	0.07	97	13.0	0.11
Orangeville	minor	94	1.6	0.21	97	16.0	0.42
Preston	major	96	0.4	0.27	97	14.0	0.38
St. Jacobs	minor	96	0.1	0.04	98	0.22	0.02
Stratford	major	95	3.7	0.21	96	4.3	0.17
Tillsonburg	major	96	0.4	0.38*	97	3.0	0.32*
Waterdown	domestic	92	12.5	0.55	96	16.0	0.60
Waterloo	major	95	0.2	0.13	96	0.6	0.18

* 1977 MOE Operating Summary indicates F/M was 0.03 day^{-1}.
+ Food-to-Microorganism Ratio.

In both sampling programs, BOD_5 removal efficiencies were high at all plants tested. BOD_5 removals exceeded 90% in all cases, except for the Hespeler and Guelph 1 plants in the summer test period, when the BOD_5 removal efficiencies were 87 and 88%, respectively. Consequently, all of the plants included in this study were producing a good quality effluent with respect to carbon oxidation.

Total ammonia-N concentrations were generally higher in the treatment plant secondary effluents during the winter program than during the summer. Total ammonia-N concentrations ranged between 0.1 and 12.5 mg/L in the summer period and from 0.2 to 26.0 mg/L during the winter program.

The food-to-microorganism (F/M) ratio is a process operating parameter describing the organic loading treated by the biological section of a treatment plant. Low food-to-microorganism ratios (e.g., 0.05 to 0.15 day^{-1}) are typical of extended aeration plants, while conventional activated sludge plants maintain an F/M ratio between 0.2 and 0.4 day^{-1}. Plants operating with an F/M ratio above 0.4 day^{-1} are considered high rate activated sludge facilities (Metcalf and Eddy, 1972). At low F/M ratios, populations of nitrifying bacteria may become well established in aeration tanks, resulting in lower total ammonia-N concentrations in effluents.

The range of F/M ratios observed in Table 7.5 suggests that the plants examined ranged from extended aeration (e.g., St. Jacobs, Grand Valley, Clarkson) through conventional activated sludge, and up to a few high rate systems (e.g., Hespeler in the winter period and Waterdown).

The process operating efficiency and industrial flow criteria were applied to the secondary effluent data to assess their impact on effluent toxicity. The resulting matrix is summarized in Table 7.6. As noted above, there were no treatment plants with BOD_5 removal efficiencies less than 80%, and so this factor cannot be evaluated. For plants discharging effluents with greater than 10 mg/L of total ammonia-N, regardless of industrial input, the effluents were usually acutely lethal. In nine of the 14 tests in this grouping (Ontario data only), acute mortality was observed in 50% or more of the samples collected from each plant. In another three tests, the effluents were classified as intermittently lethal (i.e., less than 50% of sample collected were acutely toxic).

TABLE 7.6: CATEGORIZATION AND TOXICITY OF SECONDARY EFFLUENTS BASED ON PROCESS EFFICIENCY AND INDUSTRIAL FLOW CONTRIBUTION (after Metikosh et al., 1980)

Total Ammonia-N Concentration (mg/L)	BOD_5 Removal Efficiency (%)	Domestic	Industrial Flow Component: Minor	Industrial Flow Component: Major
$NH_3 > 10$	> 80	Grand Valley (W)** Waterdown (S)** Waterdown (W)** Mission, B.C.+ Penticton, B.C.**+	Orangeville (W)*	Brantford (W)** Galt (W)* Guelph 1 (S)** Guelph 1 (W)** Guelph 2 (W)** Hamilton (W)* Hespeler (W)** Lakeview 2 (W) Lakeview 3 (W)* Preston (W)**
	< 80	Cache Creek, B.C.**+		
$NH_3 < 10$	> 80	Grand Valley (S) Prince George, B.C.+	Orangeville (S) St. Jacobs (S) St. Jacobs (W) Clarkson (S) Clarkson (W)	Brantford (S) Burlington D.L. (S) Burlington D.L. (W) Burlington Skyway (S) Burlington Skyway (W) Galt (S) Guelph 2 (S) Hamilton (S) Hespeler (S) Ingersoll 1 (S) Ingersoll 1 (W) Ingersoll 2 (S) Ingersoll 2 (W) Kitchener 1 (S) Kitchener 1 (W)* Kitchener 2 (S)* Kitchener 2 (W)* Lakeview 1 (S)* Lakeview 1 (W) Lakeview 2 (S) Lakeview 3 (S)* Preston (S) Stratford (S) Stratford (W) Tillsonburg (S) Tillsonburg (W) Waterloo (S) Waterloo (W)
	< 80			

* acute mortality in >0 to 49% of samples.
** acute mortality in >50% of samples.
+ B.C. data from survey by Higgs (1977).

(S) - summer
(W) - winter

For the treatment plants with less than 10 mg/L of total ammonia-N in their effluents, toxicity levels were much lower. Only five of the tests at Ontario plants produced acute lethality in 10 to 49% of samples collected from each plant. All of the other treatment plant effluents, with total ammonia-N less than 10 mg/L, were non-lethal. In the five tests in which toxicity was observed, there were no supporting data, such as metals or residual chlorine, which could be identified as causing toxicity.

In the study by Metikosh et al. (1980), acute lethality of the secondary effluents was demonstrated regularly when the total ammonia-N concentration exceeded 10 mg/L. Of the 14 lethal Ontario effluents (some from the same plant, but during different seasons) in this grouping, 12 were from the winter test period. This suggests a strong relationship between the time of the year, total ammonia-N concentration and effluent toxicity.

Most secondary plants were in the major industrial category, and so evaluation of importance of industrial components is difficult. The limited data suggest that the relative industrial flow contribution has little effect on the acute lethality of the secondary effluents when the total ammonia-N concentration exceeds 10 mg/L. When the effluent total ammonia-N level was less than 10 mg/L, however, industrial contribution may have had some impact on effuent toxicity. In this latter grouping, acute lethality was only observed when the industrial input was major, in five of 28 effluents tested. Two plants, Kitchener and Lakeview, were responsible for these observations. It is possible that some unidentified contaminants resulting from industrial activity were responsible for the toxic responses observed at these two plants. Because the categories for minor industrial and domestic sources are limited, it is not possible to accurately gauge the importance of industrial loading to toxicity of secondary effluents.

Data from a survey by Higgs (1977b, d, e, f) with respect to effluent toxicity in British Columbia treatment plants have also been included in Table 7.6. The four secondary effluents are all domestic, according to the industrial flow component contribution. The effluent from Cache Creek was of poorer quality, with a BOD_5 removal efficiency less than 80% (based on organic carbon and chemical oxygen demand removals), and total ammonia-N concentration greater than 10 mg/L. All effluent samples from Cache Creek were acutely toxic.

Effluents from the Mission and Penticton treatment plants both were greater than 10 mg/L in total ammonia-N, while BOD_5 removal efficiencies were in excess of 80%. All samples of the Penticton effluent were acutely lethal, while the Mission effluent samples were non-lethal.

Finally, effluent from the Prince George, B.C. plants had a total ammonia-N concentration less than 10 mg/L; the BOD_5 removal efficiency was greater than 80%. The Prince George effluent was found to be non-lethal.

The B.C. data reported by Higgs (1977) reinforce the trends noted for Ontario data summarized in the report by Metikosh et al. (1980), in that effluents tend to be acutely toxic if the total ammonia-N concentration exceeds 10 mg/L. The importance of industrial flow contribution to the B.C. plants cannot be assessed because all are domestic.

Tests were also conducted using rainbow trout on toxicity of effluents from the Waterloo and Welland treatment plants in Ontario. In both cases, BOD_5 removal efficiency was greater than 80%, and total ammonia-N concentrations were less than 10 mg/L. Welland is considered to have a major industrial flow component by the HAZPRED procedure, while the Waterloo plant has been estimated to have a minor flow component (in contrast to Metikosh et al. (1980) who reported a major industrial input for Waterloo). In both cases, the secondary effluents before disinfection were not acutely toxic to the fish.

Additional effluent toxicity data with summarized operating conditions are reported in Tables 7.7 and 7.8. The toxicity data on these two tables are not directly comparable with the results of Metikosh et al. (1980) or Higgs (1977), who reported toxicity values as the fraction of the total number of samples that were acutely lethal. The toxicity data in Tables 7.7 and 7.8 are reported as LC50 values. A number of trends are worth noting, however. The relative industrial contribution did not appear to affect effluent toxicity in Table 7.7. The Cornwall, Ontario and Winnipeg, Manitoba South End plants, both considered to treat wastewater with a major industrial contribution, were often not lethal. The result with Cornwall effluent is surprising because it is a primary treatment plant. The BOD_5 removal efficiency was only 19% in the month the toxicity testing was performed. A low ammonia-N concentration of 3 mg/L may have resulted in the relatively low toxicity of this primary effluent.

TABLE 7.7: EVALUATION OF PROCESS OPERATION ON EFFLUENT TOXICITY

Treatment Facility	Process	Stream Tested	Date (d,m,y)	BOD_5 Removal (%)	Total NH_3-N (mg/L)	F/M (day^{-1})	LC50 (% effluent)	Industrial Flow Contribution
Cornwall (MOE, 1983)	Primary	Unchlorinated Primary Effluent	08.10.77	19	3	not applicable	84	Major
Elmira (MOE, 1983)	Activated Sludge	o Secondary Effluent	20.09.76	93	16	0.06	39	
		o Chlorinated Secondary Effluent	20.09.76	93	16	0.06	GT 100	Minor
		o Secondary Effluent	12.04.77	90	20	0.09	59	
		o Secondary Effluent	13.07.82	92	16.9	no data	52	
		o Secondary Effluent, NH_3 removed	12.07.82	92	-	no data	GT 100	
		o Secondary Effluent, pH adjusted to 7.0	13.07.82	92	not specified	no data	L 100	
Paris (MOE, 1983)	Extended Aeration	o Unaerated	01.11.76	87	11.0	0.02	8	Major
		o Unaerated	14.12.77	80	14.0	no data	24	
Brampton (MOE Experimental Station (Cairns and Conn, 1979)	Activated Sludge	Secondary Effluent	03.02.75 07.11.75	avg. 92	avg. 11.2	0.3	GT 100	Minor
Winnipeg South End (Spink and Thackeray, 1979b)	Extended Aeration	Secondary Effluent	11.08.77	92	16.9	0.52 (annual average)	GT 100	Major
			17.08.77	86	1.7		GT 100	
			25.08.77	81	19.7		GT 100	
			02.09.77	-	15.7		GT 100	
			12.09.77	82	14.3		GT 100	
			20.09.77	85	19.1		GT 100	
			05.10.77	75	16.8		L 100	
			12.10.77	85	18.0		89	
			26.10.77	84	20.7		L 100	
			10.11.77	-	18.7		L 80	
			13.12.77	66	23.7		L 100	

GT = greater than.
L = less than.

TABLE 7.8: EVALUATION OF PROCESS OPERATION ON EFFLUENT TOXICITY AT REGINA, SASKATCHEWAN STP (after ref. 12)

Effluent Type	Date	BOD_5 Removal Efficiency (%)	Total NH_3-N (mg/L)	pH	LC50 (% effluent)
Alum Clarifier Effluent	08.77	99	23.4	7.1	GT 100
	09.77	98	9.2	6.8	GT 100
	09.77	96	31.7	6.8	GT 100
	09.77	98	22.6	6.9	L 100
	11.77	99	8.3	6.6	GT 100
	11.77	98	23.5	6.8	GT 100
	12.77	98	33.9	6.8	GT 100
	12.77	98	30.4	7.1	GT 100
	12.77	98	19.5	7.0	L 100
Lime Clarifier Effluent	08.77	96	17.5	11.9	L 100
	08.77	99	21.4	11.7	L 100
	09.77	99	8.5	11.8	L 100
	09.77	97	27.0	12.1	L 100
	09.77	99	23.2	12.1	L 100
	10.77	99	13.4	11.9	L 100
	11.77	99	8.3	11.6	L 100
	11.77	100	12.3	11.6	L 100
	12.77	99	29.5	11.1	L 100
	12.77	97	26.2	11.5	L 100
	12.77	97	28.9	11.3	L 100
Neutralized Lime Clarifier Effluent	08.77	96	17.5	9.3	L 100
		96	17.5	8.5	L 100
	10.77	99	13.4	5.8	GT 100
Combined Effluent Unneutralized	08.77	97	20.2	9.9	L 100
	09.77	96	7.3	10.4	L 100
	09.77	97	28.1	9.8	L 100
	09.77	98	21.9	9.6	L 100
	11.77	99	8.3	9.4	L 100
	11.77	99	31.0	9.2	10-35
	12.77	98	34.4	9.0	L 100
	12.77	98	28.9	8.9	L 100
	12.77	96	29.9	9.6	L 100
Combined Effluent Neutralized	11.77	99	8.3	7.6	GT 100
	11.77	99	31.0	8.0	73-100
	12.77	98	34.4	8.2	L 100
	12.77	96	28.9	7.6	GT 100
	12.77	96	29.9	8.4	L 100

The effect of BOD_5 removal efficiency on effluent toxicity was not well defined. Some toxicity was associated with effluents when BOD_5 removals were less than 80% (i.e., at Cornwall and Winnipeg South End). Effluent toxicity was also observed in some cases when BOD_5 removal efficiencies exceeded 80%. The data appear to indicate that effluent toxicity is more probable when the BOD_5 removal efficiency is less than 80% due to poorer removal of contaminants such as ammonia or trace organics.

No definitive trends were noted for ammonia concentrations relative to toxicity. When concentrations of ammonia exceeded 10 mg/L, the effluent was more likely to be toxic than not. The data presented in Figure 4.1 indicate that effluent toxicity is less probable if the ammonia-N concentration is less than 10 mg/L. In a number of tests, however, ammonia levels exceeded 10 mg/L and the effluent was found to be non-lethal.

In a survey of influent/effluent toxicity at six Ohio municipal activated sludge treatment plants, Neiheisel et al. (1988) concluded that toxicity reduction or pass-through at the plants did not correlate strongly with the presence or absence of industrial wastewater sources. While BOD and solids removal was efficient at all plants, toxicity reduction was highly variable. The Akron STP, for example, which receives industrial inflows, demonstrated the highest influent toxicity and also the greatest toxicity reduction.

The data for these studies of secondary effluents indicate that the total ammonia-N concentration is important to effluent toxicity. Total ammonia-N concentrations appear to be of particular concern in winter. The effect of BOD_5 removal efficiency could not be evaluated because removal efficiencies were greater than 80%. Also, the effect of industrial contributions to effluent toxicity at Ontario STPs is difficult to assess because the data do not adequately address all industrial loading categories.

7.3.3 Lagoons

Fewer data are available regarding toxicity of lagoon effluents. Metikosh et al. (1980) have reported that effluent samples from the Listowel, Markdale and Wingham lagoons during summer operation were all not acutely toxic to rainbow trout. BOD_5 removal efficiencies exceeded 80% for these lagoons, based on 1977 operating records, and total ammonia-N concentrations were in the range of 3 to 4 mg/L during the toxicity testing. Wingham and Markdale were reported to treat only domestic wastewater, while Listowel treated wastewater with a major industrial flow component (Metikosh et al., 1980).

Toxicity of the lagoon effluents during winter months was much more variable. An attempt was made to categorize the lagoon samples according to the operating efficiency and industrial input criteria using influent BOD_5 data from the 1977 and 1978 operating summaries prepared by the MOE. Monthly data corresponding to effluent BOD_5, total ammonia-N and toxicity data reported by Metikosh et al. (1980) were used where possible. Where influent BOD_5 data were missing, the 1977 or 1978 annual average was used, as appropriate. The results are summarized in Table 7.9.

Of the five lagoons tested for toxicity, only Listowel was considered to have a major industrial input, whereas the remainder were considered to treat domestic wastewater only. In the Listowel effluent, the total ammonia-N concentration exceeded 10 mg/L from February through April 1978, although the BOD_5 removal efficiency was close to or greater than 80% in this program. All effluent samples from Listowel were found to be not acutely toxic to rainbow trout, in spite of total ammonia-N concentrations as high as 12.5 mg/L as nitrogen. Effluents from the other lagoons were usually lethal to rainbow trout when the total ammonia-N concentration was greater than 10 mg/L and the BOD_5 removal efficiency was less than 80%. Although no clear trend was evident, it did appear that low BOD_5 removal (i.e., less than 80% efficiency) was an indicator of toxic effluent, possibly due to some other contaminant or factor (e.g., hydrogen sulphide or low D.O.) present under that situation. For the lagoons, an total ammonia-N concentration greater than 10 mg/L did not appear sufficient in itself to cause acute lethality; combined with low BOD_5 removal efficiency, however, total ammonia-N concentration above 10 mg/L usually resulted in toxic effluents.

Two biological degradation mechanisms operate in lagoon treatment systems which are not aerated. At the surface, the exchange of oxygen allows aerobic bacteria to oxidize nitrogenous wastes (nitrification). In the anaerobic layer beneath, different bacteria degrade organic matter to methane. These bacteria will preferentially reduce available sulphates causing the production of H_2S. The H_2S is released as a gas during most of the year, but remains dissolved in the water when ice cover prevents its escape. Toxicity is related to the amount of H_2S versus HS^- and is pH-dependent. Decomposition in the winter tends to depress the pH of the lagoon causing the equilibrium to shift towards the production of H_2S, making the effluent progressively more toxic. Peak toxicty in lagoons likely occurs at the time of spring turnover (the rising temperature causes the ice to melt and the mixing of the water column) when H_2S trapped in bottom sediments is added to that accumulated in the water column.

TABLE 7.9: CATEGORIZATION AND TOXICITY OF LAGOON EFFLUENTS BASED ON PROCESS EFFICIENCY AND INDUSTRIAL FLOW CONTRIBUTION (after Metikosh et al., 1980)

Effluent Total Ammonia-N (mg/L)	BOD_5 Removal Efficiency (%)	Domestic Input		Major Industrial Input	
$NH_3 > 10$	> 80%	Markdale	12.77[+]	Listowel	02.78.01
			01.78.01		02.78.02
			04.78.02**		03.78.02
			05.78**		04.78
		Tavistock	05.78		
	< 80%	Markdale	01.78.02	Listowel	03.78.01
			01.78.03**		
			02.78**		
			03.78.02**		
			04.78.01**		
		Wingham	02.78.02**		
			03.78.01**		
			03.78.02**		
		Mitchell	03.78**		
		Tavistock	01.78**		
			02.78**		
$NH_3 < 10$	> 80%	Wingham	01.78.01	Listowel	12.77
			01.78.02		01.78.01
			02.78.01*		01.78.02
			05.78*		
		Mitchell	12.77		
			01.78		
		Tavistock	12.77		
	< 80%	Wingham	12.77		
			04.78.01**		
			04.78.02		
		Mitchell	02.78**		
			04.78		
		Tavistock	03.78**		

* acute mortality in > 0 to 49% of samples.

** acute mortality in > 50% of samples.

[+] Recorded as month·year.

Since aerated lagoons have at most only a shallow anaerobic layer on the bottom, H_2S is not produced in great quantity. In addition, with sufficient retention times, nitrification is enhanced over non-aerated cells. Both factors would lead to a less toxic effluent, and was demonstrated in the experiment by Metikosh et al. (1980) where the aerated lagoon effluent from Listowel was consistently non-toxic even during the winter.

Higgs (1977) reported that two lagoons in British Columbia at Williams Lake and Clinton produced effluents that were not acutely toxic when tested in August 1976. Although BOD_5 removal efficiency could not be determined, total ammonia-N concentrations were 1.7 mg/L for Clinton and 0.2 mg/L for Williams Lake. The results are consistent with Ontario lagoon effluents tested in the summer by Metikosh et al. (1980).

The results of a toxicity testing program at the Regina, Saskatchewan STP are reported in Table 7.8. In all tests, BOD removal efficiencies were greater than 80%. Whenever the ammonia concentration in the effluent was less than 10 mg/L and when the pH was less than 8.0, effluents were non-lethal. Addition of lime for enhanced suppended solids or phosphorus removal caused effluent pH values to increase. At elevated pHs, effluents were found to be lethal even when ammonia-N levels were less than 10 mg/L. The lethality of the effluents with higher pH values (greater than 8) was due in part to higher concentrations of unionized ammonia, as discussed in greater detail in Section 4.1.

In toxicity tests conducted on effluent treated with alum, or with lime followed by neutralization, samples were found to be non-lethal, with ammonia levels above 10 mg/L and as high as 33.9 mg/L (Table 7.8). The Regina data also indicate that effluents are not likely to be toxic if the total ammonia concentration is less than 10 mg/L, and where pH is less than 8.0. Effluents may not be toxic at total ammonia-N levels greater than 10 mg/L but, under the observed conditions, at neutral pH, some were observed to be toxic when ammonia-N exceeded 10 mg/L.

The lagoon effluent toxicity data are limited. Toxicity was observed in winter and not summer samples. The toxicity in winter appeared to be due to a combination of total ammonia-N levels above 10 mg/L and other factors operative when the BOD_5 removal efficiency was less than 80%. Elevated total ammonia-N concentrations alone did not appear to be solely responsible for lagoon effluent toxicity. The effect of industrial input to a lagoon on effluent toxicity could not be assessed.

7.4 Upset of STPs by Chemicals or pH

Effluent quality depends on the operating efficiency of an STP. Toxicity of an effluent may also depend on how well the treatment process is functioning. Wastewater containing elevated levels of chemicals or extreme pH values may disrupt the treatment processes (particularly biological processes) resulting in discharge of poor quality and/or toxic effluents. In order to assess the extent of the problem, provincial MOE and municipal officers were contacted to provide specific information on treatment plant upsets that were caused by chemicals or pH.

A list of the officers contacted in this survey is provided in Table 7.10. In general, the survey identified few treatment plants that were experiencing operating problems due to chemicals or extreme pH values in the wastewater. The most common response was that the officers were not aware of any problems at STPs under their jurisdiction.

Plants where problems were specifically identified are summarized in Table 7.11. The cause of the upsets included textile industry related chemicals, metals, surfactants and acidic or alkaline wastes.

Excessive foam, reduced aeration efficiency, higher effluent BOD_5 and suspended solids levels are associated with surfactants at the Lakeview, Elmira, North Toronto and Cobourg plants. Process upsets as a result of caustic soda causing elevated pH values were relatively isolated events at Huron Park and North Toronto. The Cobourg treatment plant has experienced both acidic and alkaline conditions, resulting in higher effluent BOD_5 and suspended solids, on a more regular basis. Metals have been implicated as causing process difficulties at Oshawa Harmony Creek No. 1 and Cobourg, but the problems are reported to last less than a week. Elevated nickel concentration in wastewater treated by the Watt's Creek treatment plant did not affect the activated sludge process, but the anaerobic digesters were adversely affected and did not recover for two to three months.

At some plants, process upsets are a single isolated event, while other plants suffer operating difficulties on a frequent basis (e.g., Iroquois, Mississauga, Lakeview). Most plants indicate that they recover in a relatively short period of time (e.g., less than a week), and so no major remedial action is taken. The greatest observed impact of the

TABLE 7.10: SURVEY OF POLLUTION CONTROL OFFICIALS CONCERNING STP UPSETS CAUSED BY CHEMICALS OR pH

Affiliation	Contact	Comments
MOE, London South	Fred Durham	No reply
MOE, London North	Vic Danely	Some plating operations discharge to plants, but cause no problem
MOE, Owen Sound	Willard Page	See Table 7.11
MOE, Sarnia	Kal Haniff	No reply
MOE, Windsor	Jim Drummond	No reply
MOE, Cambridge	Bruce Kramer	No problems noted
MOE, Haldimand-Norfolk-Brant	John Cooke	Only problems are related to excessive BOD_5 from cannery and pickle packer
MOE, Hamilton-Wentworth	John Vogt	Hamilton plant suffered BOD overload due to vegetable oil spill
MOE, Welland	Dave Ireland	No problems noted
MOE, Barrie	Ian Gray/Roy Frederick	No problems noted
MOE, Halton-Peel	George Nelson	No problems noted
MOE, Metro Toronto East	Russ Boyd/Mike Thorn	No problems noted
MOE, Metro Toronto West	John Mills/ Frank Morton	Hastings plant was overlooked by BOD discharged by a leather tannery
MOE, Muskoka-Haliburton	Terry Healy	No problems noted
MOE, Peterborough	Jacques Bourque	No problems noted
MOE, York-Durham	Don Perie	No problems noted
MOE, Cornwall	Bill Spencer/ Ron Robertson	Iroquois plant - see Table 7.11
MOE, Kingston	Don Currie/Jack Pruner	No problems noted

TABLE 7.10: SURVEY OF POLLUTION CONTROL OFFICIALS CONCERNING STP UPSETS CAUSED BY CHEMICALS OR pH

Affiliation	Contact	Comments
MOE, Ottawa	Bob Dunn/Dick Gietz	Watts Creek - see Table 7.11
MOE, North Bay	Gord Johnson	No problems noted
MOE, Sault Ste. Marie	Bruce Cave/Mort Taylor	No problems noted
MOE, Sudbury	Lawrence Oliviar	No problems noted
MOE, Timmins	Ken Gibson	No problems noted
MOE, Kenora	John Barr	No problems noted
MOE, Thunder Bay	Dave Shantz	No problems noted
Region of Halton	Len Yust	No problems noted
Region of Niagara	Mike Glynn	No problems noted
Region of Peel	Gerry Healy	See Table 7.11
City of London	R.J. Collins	No problems noted
Region of Waterloo	Dave Andrews	No problems noted
Elmira WPCP	Don Nicholls	See Table 7.11
Cobourg WPCP	Brian Davey	See Table 7.11
Region of Hamilton-Wentworth	Joe Blake	No problems noted
Metro Toronto	Vic Lim	See Table 7.11
Oshawa Harmony Creek	Leslie Birta Peter Rupke	See Table 7.11

TABLE 7.11: SUMMARY OF ONTARIO STP UPSETS CAUSED BY CHEMICALS OR pH

Treatment Plant	Cause of Upset	Frequency	Effect on Plant	Corrective Measure
Iroquois	Sodium hydrosulfite (dye stabilizer)	Regularly	Produces H_2S and odour problems	Installing pre-aeration for H_2S removal
	Metal fixative for dyes	Regularly	Affects phosphorus removal	None as yet
Nepean (Watts Creek)	Nickel in anaerobic digester	Once, Spring 1983	Digester gas production stopped	Lime addition plus reseeding with sludge from Green's Creek digesters. Downtime was approx. two to three months
Mississauga (Lakeview)	Non-ionic surfactant	Monthly; each episode lasted a few hours	Foam, high BOD_5 in effluent	Problem corrected at source
Huron Park	Caustic soda	Spring 1986 December 1986	pH 12 or higher, killed mixed liquor	Did not reseed; wasted aeration to digesters; back in operation in eight to nine days
Woolwich Twp. (Elmira)	Surfactant (?)	Approx. 3 to 4 times per year	Heavy foam in aeration tanks and clarifiers clogs sand filters, causes high effluent suspended solids	Change in location of anti-foam injection by chemical plant
North Toronto	Surfactant	Once per year or less	Temporary higher effluent BOD	None; only lasts for a day or two
	Caustic	Once approx. 6 years ago	High pH killed mixed liquor	None; operational after two weeks
Cobourg	Cr, Zn, Pb, pH and surfactant	Approx. 3 to 4 times per year	Elevated BOD_5 and TSS for approx. two days	None; only lasts for about two days
	Unknown discharge from tannery	Twice in 1987	Toxic effect on mixed liquor caused high BOD and TSS	None due to unknown substance; each episode lasted about one month
Oshawa Harmony Creek No. 1	Plating waste	Approx. every other week	Trickling filter changes colour, loses solids in effluent	None
Oshawa Harmony Creek No. 2	Pesticides	Every spring for the last 3 years	Substantial toxic impact on mixed liquor biomass; higher effluent BOD_5 and TSS	None

process upsets is reported to be deteriorating effluent quality based on BOD_5 and TSS measurements. Effluent toxicity as a result of these process upsets has not been determined.

The survey has indicated that certain treatment plants are subject to process upsets due to chemicals or pH excursions. It is perhaps surprising that more treatment plants were not identified as having process upsets due to pH or chemical problems. This may be due to a lack of communications between operating and administrative staff, or a reluctance to indicate that a treatment plant is suffering from process upsets.

7.5 Summary

Data relating industrial input to sewage treatment plant effluent toxicity is limited, particularly with respect to plants receiving domestic wastewater only, or wastewater with a minor industrial input. However, descriptions of final effluent toxicity as a function of plant treatment type, hydraulic loading as a fraction of design capacity, BOD removal, and effluent concentrations of ammonia were adequate to identify discrete groups of sewage treatment plants.

Primary effluents were almost always observed to be acutely lethal. Both high total ammonia-N concentrations and poor BOD_5 removal efficiency (less than 80%), as well as other factors such as trace contaminants, may be responsible for the toxic effects. The importance of industrial loadings in primary plants could not be assessed.

Secondary plants, in spite of high BOD_5 removal efficiencies (e.g., greater than 80%), effluents were frequently toxic if the total ammonia N concentration exceeded 10 mg/L. This was very often the case during winter operation. with high total ammonia-N levels apparently resulting from reduced nitrification at lower wastewater temperatures. In the secondary plants where total ammonia-N did not appear to be the controlling toxic contaminant, some moderate toxicity may result from industrial contaminants. Again, because of the limited database, the importance of poor BOD_5 removal efficiency and industrial flow contribution could not be evaluated.

Lagoon effluent toxicity was most frequently associated with both high total ammonia-N concentrations and poor BOD_5 removal efficiency, rather than with high total ammonia-

N concentrations alone. Toxicity data for lagoon effluents were, however, very limited. As with the primary effluents, the toxicity may be due to ammonia or other toxicants such as hydrogen sulphide that may be present under conditions characterized by poor BOD_5 removal efficiency. The importance of industrial loadings to lagoon effluent toxicity could not be evaluated.

Based on the review of treatment process operations, total ammonia-N appears to be the most reliable indicator of acute lethality measured in sewage treatment plant effluents. It should be emphasized, however, that the studies reviewed could not provide sufficient evidence to assess the importance of BOD_5 removal efficiency or industrial contributions.

8.0 CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

Review of toxicity and process data for plants indicated that:

- The available Ontario and Western Canada primary STP data indicate primary effluents are generally acutely lethal. Secondary and lagoon treatment plants produce effluents of variable quality. It would seem, therefore, that lethality is not related simply to the type of treatment process involved (i.e., primary, secondary or lagoon), but to conditions specific to each plant as well.
- Ammonia toxicity has been demonstrated in laboratory tests of STP effluents in Ontario. Chlorine toxicity in effluents has been shown in continuous-flow tests in the laboratory, as well as in in situ field studies. Conventional static bioassays allow dissipation of total residual chlorine and, therefore, result in an inaccurate reflection of its toxic potency. At some STPs, other toxic components may be involved (i.e., metals, surfactants, organics, etc.).
- Process operating efficiency, as measured in terms of NH_3-N is a more reliable determinant of effluent lethality than the type or amount of industrial input. However, the data available for this review on industrial inputs were limited.
- Both high total ammonia-N concentrations and poor BOD_5 removal efficiency may be responsible for the toxic effluents from primary plants.
- In secondary plants, in spite of high BOD_5 removal efficiencies (e.g., greater than 80%), effluents were frequently toxic if the total ammonia-N concentration exceeded 10 mg/L. This was very often the case during winter operation, with high total ammonia-N levels apparently resulting from reduced nitrification at lower wastewater temperatures.
- Effluent toxicity associated with lagoon operation was most frequently associated with both high total ammonia-N concentrations and poor BOD_5 removal efficiency, rather than with high total ammonia-N concentrations alone. As with the primary effluents, the toxicity may be due to ammonia or other toxicants such as hydrogen sulphide.

- The amount of receiving water dilution available for an effluent will determine the downstream area where toxic effects will be observed. Receiving water lethality has been demonstrated in effluent plumes below some Ontario STP outfalls. Estimated instantaneous dilution factors for several Ontario STPs suggest that there are undoubtedly some plants which will generate substantial toxic impact zones. The physical and chemical characteristics of each receiving water body may also affect the toxicity of various components of the effluent, as well as their persistence.
- Biological tests of treatment plant effluents can reliably predict whether the receiving waters are affected by the discharge. Acute and chronic tests with a variety of representative receiving water species provide a good estimation of field effects.
- Information on sublethal or chronic effects of treated STPs' effluents was limited in the literature.

8.2 Recommendations

The authors of this report recommend that an intensive evaluation of STP effluent toxicity be completed on selected plants from each category identified in Table 8.1 to demonstrate achievable effluent quality expressed as acute and/or chronic toxicity in well operated sewage treatment plants. The following items should be incorporated in the study:

- the 10 mg/L total ammonia "toxicity indicator level" should be verified and the data expressed as the toxic un-ionized ammonia concentration to improve comparability of the data;
- sublethal or chronic toxicty tests of effluent quality should be included in the field program;
- toxic effluents should be further analyzed to identify toxic agents; and
- field assessments should be completed to more clearly define the limits of TRC toxicity and distinguish effects from those attributable to other toxicants. Field calibration of laboratory data would then improve interpretation of laboratory test results.

The Ontario sewage treatment plants listed in Table 8.1 have been selected with the above recommendations in mind and through the use of the following selection criteria:

- hydraulic loading of 75 to 110% of design capacity;
- BOD removal efficiency of 80% for lagoons and secondary plants, and 50% for primary plants; and
- effluent ammonia concentration of less than 10 mg/L for zero to six months, or less than 10 mg/L on an annual basis.

TABLE 8.1: LIST OF CANDIDATE STPs FOR FULL-SCALE EFFLUENT TOXICITY MONITORING PROGRAM

Industrial Component	Primary	Secondary		Lagoons
Domestic	Kingston Fort Erie (Anger Avenue)	Vaughan Halton Hills (Acton) Onaping Falls (Onaping) Onaping Falls (Levack) Onaping Falls (Dowling) Bracebridge	London (Oxford) Penetanguishene Gravenhurst Haldimand (Caledonia) Timmins (Whitney)	Lakefield Brighton* Nanticoke (Waterford)* Kincardine*
Minor	Owen Sound Prescott Thunder Bay	Guelph Flamborough Walkerton Welland Peterborough Sudbury Orillia	London (Adelaide) London (Greenway) London (Pottersburg) Whitby (Pringle Cr. No. 1) Huntsville Milton Waterloo	Alexandria Lindsay Perth Niagara-on-the-Lake Strathroy
Major	Windsor (Westerly) Gloucester (Greens Cr.)	Chatham Mississauga (Lakeview) Midland Halton Hills (Georgetown) Port Colborne (Seaway) Pickering (Duffins Cr.)	Metro Toronto (North) London (Vauxhall) Stratford Port Hope Oshawa (Harmony Cr. No. 1) Whitchurch-Stouffville	

Selection Criteria:

1. Hydraulic loading 75 to 110% of design flow.

2. BOD removal efficiency: 80% for lagoons and secondary
50% for primary plants

3. Effluent ammonia concentration: Less than 10 mg/L for 0 to 6 months, or
Less than 10 mg/L on an annual basis

* Less than 75% of design flow.

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APPENDIX A

Summary of Historical STP Effluent Toxicity Data

Table A1: Ontario STPs

Table A2: Other Canadian STPs

TABLE A1: TOXICITY OF EFFLUENTS FROM ONTARIO STP's

Facility	Receiving Water	Sampling Date (m.y)	Effluent Type	STP Flow Rate	Treatment Process	pH	NH_3-N (mg/L)	TRC (mg/L)	Test Org.	Life Stage	Test Type	Duration/ Procedure	LC50 (% effluent)	Comments	Ref.
Alexandria	Delisle R.	10.08.77	Lagoon Outfalls		WSP (CD; A)	7.5			Sg	0.8 g	L/S	96-h LC50	GT 100		1
		25.08.81	A Cell			7.4							GT 100		
		25.06.81	B Cell			7.6							GT 100		
		25.06.81	C Cell			7.7							GT 100		
Brampton (MOE Experimental		03.02.75-07.11.75	Nonchlor.		CAS				Sg		L/CF	96-h LC50	GT 100	2/17 samples lethal; NH_3-N of 18 mg/L in both	2
Station		03.02.75-07.11.75	Dechlor.		CAS				Sg		L/CF	96-h LC50	GT 100	0/5 samples lethal after dechlorination with sodium sulphite	2
		02.75	Chlor.		CAS			0.5*	Sg		L/CF	96-h LC50	L 100	*TRC = nominal conc.	2
		02.75						1.5					L 100		
		02.75						0.5					L 100		
		03.75						2.5					L 100		
		03.75						2.5					L 100		
		03.75						0.5					L 100		
		04.75						1.5					L 100		
		04.75						0.5					L 100		
		04.75						1.0					L 100		
		04-05.75						1.0					L 100		
		09.75						1.0					L 100		
		10.75						1.0					L 100		
Brantford	Grand R.	08-10.77	Nonchlor.		CAS		0.5		Sg	2.6 g	L/S	24-h in 100%	GT 100	0/10 samples lethal	3
		01-02.78					10.0						L 100	3/5 samples lethal	3
Burlington (Drury L.)	L. Ontario	08-10.77	Nonchlor.		EA		0.6		Sg	2.6 g	L/S	24-h in 100%	GT 100	0/9 samples lethal	3
		01-02.78					0.8				L/S		GT 100	0/5 samples lethal	3
Burlington (Skyway)	Hamilton H.	04.10.76	Nonchlor.		EA	7.9			Sg	2.6 g	L/S	96-h LC50	GT 100	10% mort. in 100%	1
		08-10.77			CAS		9.2				L/S	24-h in 100%	GT 100	0/9 samples lethal	3
		01-02.78			CAS		2.2				L/S		GT 100	0/5 samples lethal	3
Clarkson	L. Ontario	08-10.77	Nonchlor.		EA		0.2		Sg	2.6 g	L/S	24-h in 100%	GT 100	0/10 samples lethal	3
		01-02.78					0.34						GT 100	0/5 samples lethal	3
Cornwall	St. Lawrence R.	08.10.77	Nonchlor.		Primary	6.7			Sg	0.8 g	L/S	96-h LC50	84		1
		25.06.81	Chlor.			7.2							GT 100		
Elmira	Canagagigue Creek	20.09.76	Nonchlor.		CAS	7.5			Sg	0.8 g	L/S	96-h LC50	GT 100		1
		14.07.81				7.6							54		
		20.09.76				7.4							39		
		12.04.77				7.6							59		
		13.07.82				8.0							52		
		13.07.82	Nonchlor., treated			8.2							GT 100	Treated with clinoptilolite	
		13.07.82	Nonchlor.			7.0							L 100	pH adjusted to 7.0; 100% mortality in 100%	

TABLE A1: TOXICITY OF EFFLUENTS FROM ONTARIO STP's (cont'd)

Facility	Receiving Water	Sampling Date (m.y)	Effluent Type	STP Flow Rate	Treatment Process	pH	NH_3-N (mg/L)	TRC (mg/L)	Test Org.	Life Stage	Test Type	Response	LC50 (% effluent)	Comments	Ref.
Galt	Grand R.	08-10.77	Nonchlor.		CAS		2.4		Sg	2.6 g	L/S	24-h in 100%	GT 100	0/10 samples lethal	3
		01-02.78					10.0						L 100	1/5 samples lethal	3
		30.09.86		High		7.5			Dm	L 24 h	L/S	48-h LC50	GT 100		4
		01.10.86				6.7							GT 100		
		02.10.86				8.0							GT 100		
		03.10.86				7.4							GT 100		
		04.10.86				7.4							GT 100		
		05.10.86				7.4							GT 100	20% mortality in 100%	
		06.10.86				7.5							GT 100	20% mortality in 100%	
		07.10.86				7.4							GT 100	10% mortality in 100%	
		08.10.86				7.3							84		
		30.09.86	Chlor.	High	CAS	7.4	15.0	0.05					GT 100		
		01.10.86				7.8	15.0	0.30					GT 100		
		02.10.86				8.0	15.0	0.35					GT 100		
		03.10.86				7.4	15.0	0.35					GT 100		
		04.10.86				7.5	20.0	0.18					GT 100		
		05.10.86				7.6	22.5	0.38					GT 100	10% mortality in 100%	
		06.10.86				7.5	23.0	0.35					GT 100		
		07.10.86				7.5	28.0	0.10					GT 100	20% mortality in 100%	
		08.10.86				7.4	12.7	0.10					66		
		01.10.86	Nonchlor.	Low	CAS	7.5							GT 100		
		02.10.86				7.7							GT 100		
		03.10.86				7.4							GT 100		
		04.10.86				7.4							GT 100		
		05.10.86				7.4							GT 100		
		06.10.86				7.4							GT 100	10% mortality in 100%	
		07.10.86				7.4							GT 100		
		08.10.86				7.4							GT 100		
		01.10.86	Chlor.	Low	CAS	7.5	16.2	0.18					GT 100		
		02.10.86				7.8	23.0	0.13					GT 100		
		03.10.86				7.4	20.0	0.15					GT 100		
		04.10.86				7.4	21.8	0.18					GT 100		
		05.10.86				7.6	19.5	0.38					GT 100		
		06.10.86				7.8	23.0	0.50					100		
		07.10.86				7.5	19.0	0.15					GT 100		
		08.10.86				7.4	27.0	0.10					GT 100		
		05.10.86	Nonchlor.	High	CAS				Cd	4 h	L/S	168-h LC50	88		4
		06.10.86											46		
		07.10.86	Chlor.	Low	CAS	7.4	19.0	0.15					GT 100	20% mortality in 100%	
		08.10.86				7.3	27.0	0.10					76		
		05.10.86	Nonchlor.	High	CAS				Cd	4 h	L/S	Reproductive Effects	71		4
		06.10.86											39		
		07.10.86	Chlor.	Low	CAS	7.4	19.0	0.15					71		
		08.10.86				7.3	27.0	0.10					71		

TABLE A1: TOXICITY OF EFFLUENTS FROM ONTARIO STP's (cont'd)

Facility	Receiving Water	Sampling Date (m.y)	Effluent Type	STP Flow Rate	Treatment Process	pH	NH_3-N (mg/L)	TRC (mg/L)	Test Org.	Life Stage	Test Type	Response	LC50 (% effluent)	Comments	Ref.
Grand Valley	Grand R.	08-10.77 01-02.78	Nonchlor.		EA		1.2 26.0		Sg	2.6 g	L/S L/S	24-h in 100%	GT 100 L 100	0/8 samples lethal 5/5 samples lethal	3 3
Guelph 1	Speed R.	08-10.77 01-02.78	Nonchlor.		CAS		10.6 12.0		Sg	2.6 g	L/S	24-h in 100%	L 100 L 100	5/10 samples lethal 3/5 samples lethal	3
Guelph 2	Speed R.	08-10.77 01-02.78	Nonchlor.		CAS		7.8 16.0		Sg	2.6 g	L/S	24-h in 100%	GT 100 L 100	0/9 samples lethal 4/5 samples lethal	3
Hamilton	Hamilton H.	08-10.77 01-02.78	Nonchlor.		CAS		9.7 14.4		Sg	2.6 g	L/S	24-h in 100%	GT 100 L 100	0/8 samples lethal 2/5 samples lethal	3
Hawkesbury	Ottawa R.	08.10.77	Above Dam Discharge		EA	7.5			Sg	0.8 g	L/S	96-h LC50	100		1
Hespeler	Speed R.	08-10.77 01-02.78	Nonchlor.		CAS		8.2 12.3		Sg	2.6 g	L/S	24-h in 100%	L 100 L 100	3/10 samples lethal 4/5 samples lethal	3
Ingersoll	Thames R.	12.12.79 10.04.80 12.04.80	Nonchlor. Nonchlor. Chlor.		CAS	7.9 - -			Sg		L/S	24-h LC50 96-h LC50	GT 100 GT 100 43		1
Ingersoll 1	Thames R.	08-10.77 01.02.78	Nonchlor.		EA		0.3 0.5		Sg	2.6 g	L/S	24-h in 100%	GT 100 GT 100	0/9 samples lethal 0/5 samples lethal	3
Ingersoll 2	Thames R.	08-10.77 01.02.78	Nonchlor.		CAS		0.9 5.0		Sg	2.6 g	L/S	24-h in 100%	GT 100 GT 100	0/9 samples lethal 0/5 samples lethal	3
Iroquois	St. Lawrence R.	10.08.77	Chlor.		Primary	7.1			Sg		L/S	96-h LC50	38	0% mort. in 30%, 100% at 50%	1
Kitchener 1	Grand R.	08-10.77 01-02.78	Nonchlor.		EA		0.3 7.5		Sg	2.6 g	L/S	24-h in 100%	GT 100 L 100	0/9 samples lethal 1/5 samples lethal	3
Kitchener 2	Grand R.	08-10.77 01-02.78	Nonchlor.		EA		1.2 9.4		Sg	2.6 g	L/S	24-h in 100%	L 100 L 100	1/10 samples lethal 1/5 samples lethal	3
Lakeview 1	L. Ontario	08-10.77 01-02.78	Nonchlor.		CAS		5.1 1.4		Sg	2.6 g	L/S	24-h in 100%	L 100 GT 100	1/11 samples lethal 0/5 samples lethal	3
Lakeview 2	L. Ontario	08-10.77 01-02.78	Nonchlor.		CAS		7.7 13.0		Sg	2.6 g	L/S	24-h in 100%	GT 100 GT 100	0/7 samples lethal 0/5 samples lethal	3
Lakeview 3	L. Ontario	08-10.77 01-02.78	Nonchlor.		CAS		2.6 13.0		Sg	2.6 g	L/S	24-h in 100%	L 100 L 100	2/10 samples lethal 1/5 samples lethal	3

TABLE A1: TOXICITY OF EFFLUENTS FROM ONTARIO STPs (cont'd)

Facility	Receiving Water	Sampling Date (m.y)	Effluent Type	STP Flow Rate	Treatment Process	pH	NH_3-N (mg/L)	TRC (mg/L)	Test Org.	Life Stage	Test Type	Response	LC50 (% effluent)	Comments	Ref.
Lindsay	Scugog R.	06.03.78	Chlor.		WSP (CD; A)	6.9			Sg		L/S	96-h LC50	52		1
		06.03.78				7.5							66		
Listowel	Chapman Drain	07-08.77	Nonchlor.		WSP (CD; A)		3.0		Sg	2.6 g	L/S	24 h in 100% conc.	GT 100	0/10 samples lethal	3
		12.77					7.5						GT 100	0% mortality	
		01.78					8.5						GT 100	0% mortality	
		01.78					9.0						GT 100	0% mortality	
		02.78					10.5						GT 100	0% mortality	
		02.78					11						GT 100	0% mortality	
		03.78					12						GT 100	0% mortality	
		03.78					12.5						GT 100	0% mortality	
		03.78					12						GT 100	0%	
Markdale	Rocky Saugeen R.	07-08.77	Nonchlor.		WSP (CD; NA)		4.0		Sg	2.6 g	L/S	24 in 100% conc.	GT 100	0/9 samples lethal	3
		12.77					10.5						GT 100	0% mortality	
		01.78					12						GT 100	0% mortality	
		01.78					13.3						GT 100	0% mortality	
		01.78					13.5						L 100	90% mortality	
		02.78					16						L 100	100% mortality	
		03.78					-						L 100	100% mortality	
		03.78					21						L 100	100% mortality	
		04.78					16						L 100	100% mortality	
		04.78					14						L 100	80% mortality	
		05.78					12						L 100	60% mortality	
Mitchell	Thames R.	12.77	Nonchlor.		WSP (SD)		1.2		Sg	2.6 g	L/S	24 in 100% conc.	GT 100	0% mortality	3
		01.78					5.5						GT 100	0% mortality	
		02.78					6.0						L 100	100% mortality	
		03.78					11.2						L 100	100% mortality	
		04.78					8.5						GT 100	0% mortality	
Orangeville	Credit R.	08-10.77	Nonchlor.		CAS		1.6		Sg	2.6 g	L/S	24-h in 100%	GT 100	0/9 samples lethal	3
		01-02.78					16.0						L 100	2/6 samples lethal	
Paris	Grand R.	01.11.76	Unaer.		EA	7.7			Sg		L/S	96-h LC50	8		1
		14.12.77				7.6							24		
		17.03.81	Nonchlor.			7.8							61		
		19.03.81				8.0							54		
Preston	Grand R.	08-10.77	Nonchlor.		CAS		0.4		Sg	2.6 g	L/S	24-h in 100%	GT 100	0/10 samples lethal	3
		01-02.78					14.0						L 100	4/5 samples lethal	
St. Jacobs	Conestoga River	08-10.77	Nonchlor.		EA		0.1		Sg	2.6 g	L/S	24-h in 100%	GT 100	0/9 samples lethal	3
		01-02.78					0.22						GT 100	0/5 samples lethal	

TABLE A1: TOXICITY OF EFFLUENTS FROM ONTARIO STP's (cont'd)

Facility	Receiving Water	Sampling Date (m.y)	Effluent Type	STP Flow Rate	Treatment Process	pH	NH_3-N (mg/L)	TRC (mg/L)	Test Org.	Life Stage	Test Type	Response	LC50 (% effluent)	Comments	Ref.
Stratford	Avon River	08-10.77	Nonchlor.		CAS		3.7		Sg	2.6 g	L/S	24-h in 100%	GT 100	0/9 samples lethal	3
		01-02.78					4.3						GT 100	0/5 samples lethal	
Tavistock		12.77	Nonchlor.		WSP (SD)		5.5		Sg	2.6 g	L/S	24 in 100% conc.	GT 100	0% mortality	3
		01.78					17						L 100	100% mortality	
		02.78					16						L 100	100% mortality	
		03.78					9.0						L 100	100% mortality	
		05.78					11						GT 100	0% mortality	
Tillson-burg	Big Otter Creek	08-10.77	Nonchlor.		CAS		0.4		Sg		L/S	24-h in 100%	GT 100	0/10 samples lethal	3
		01-02.77					3.0						GT 100	0/5 samples lethal	
Waterdown		08-10.77	Nonchlor.		CAS		12.5		Sg	2.6 g	L/S	24-h in 100%	L 100	5/10 samples lethal	3
		01-02.78					16.0						L 100	3/5 samples lethal	
Waterloo	Grand R.	08.10.77	Nonchlor.		CAS		0.2		Sg	2.6 g	L/S		GT 100	0/9 samples lethal	3
		01.02.78					0.6						GT 100	0/5 samples lethal	
		02.07.86	Nonchlor.	High	CAS	7.2			Dm	24 h	L/S	48-h LC50	GT 100		5
		04.07.86				7.2							GT 100		
		06.07.86				7.2							GT 100		
		09.07.86				8.0							GT 100		
		10.07.86				7.6							GT 100		
		02.07.86	Chlor.	High	CAS	7.2	1.7	0.24	Dm	24 h	L/S	48-h LC50	GT 100	10% mortality	5
		04.07.86				7.2	1.85	0.05					GT 100		
		05.07.86				7.5	3.2	0.20					GT 100		
		06.07.86				7.6	1.75	0.12					GT 100		
		08.07.86				8.0	1.7	0.10					GT 100		
		09.07.86				7.9	3.5	0.27					GT 100		
		10.07.86				7.4	1.7	0.22					GT 100		
		03.07.86	Nonchlor.	Low	CAS	7.1			Dm	24 h	L/S	48-h LC50	GT 100	20% mort. in 100%	5
		04.07.86				7.2							GT 100		
		06.07.86				7.1							GT 100		
		09.07.86				7.5							GT 100		
		10.07.86				7.6							GT 100		
		03.07.86	Chlor.	Low	CAS	7.0	1.0	0.05	Dm	24 h	L/S	48-h LC50	GT 100	20% mort. in 100%	5
		04.07.86				7.1	1.05	0.17					GT 100		
		05.07.86				7.5	4.0	0.02					GT 100		
		06.07.86				7.5	1.4	0.05					GT 100		
		09.07.86				7.3	3.5	0.12					GT 100		
		10.07.86				7.5	1.5	0.16					GT 100		
		04.07.86	Chlor.	High	CAS	7.0	1.85	0.05	Sg	0.8 g	L/S	96-h LC50	GT 100		5
		06.07.86				7.2	1.75	0.12					GT 100		
		04.07.86	Nonchlor.	Low	CAS	7.2							GT 100		
		06.07.86				7.7							GT 100		
		04.07.86	Chlor.	Low	CAS	8.1	1.05	0.17					GT 100		
		06.07.86				7.1	1.4	0.05					GT 100		
		04.07.86	Nonchlor.	High	CAS	7.3							GT 100		
		06.07.86				7.2							GT 100		

Facility	Receiving Water	Sampling Date (m.y)	Effluent Type	STP Flow Rate	Treatment Process	pH	NH_3-N (mg/L)	TRC (mg/L)	Test Org.	Life Stage	Test Type	Response	LC50 (% effluent)	Comments	Ref.
Waterloo (cont'd)	Grand R.	02.07.86	Chlor.		CAS	8.0		0.074	Sg	1.2 g	L/S	96-h LC50	GT 100		7
		04.07.86				7.8		0.188					GT 100		
		07.07.86				7.9		0.060					GT 100		
Welland	Welland R.	19.08.86	Nonchlor.	High	CAS	7.2			Dm	24 h	L/S	48-h LC50	GT 100		6
		20.08.86				7.2							GT 100		
		22.08.86				7.1							GT 100		
		24.08.86				7.2							GT 100		
		27.08.86				7.1							GT 100		
		19.08.86	Chlor.	High	CAS	7.4	7.2	0.11					GT 100		
		20.08.86				7.2	3.5	0.68					GT 100		
		22.08.86				7.0	7.0	1.10					17		
		23.08.86				7.0	11.3	0.72					8	71 after NH_3 rem.	
		24.08.86				7.1	5.5	0.01					GT 100		
		27.08.86				7.2	1.6	0.70					12		
		20.06.86	Nonchlor.	Low	CAS	7.1							GT 100		
		21.08.86				7.1							GT 100		
		22.08.86				6.9							GT 100		
		24.08.86				7.0							GT 100		
		27.08.86				7.1							GT 100		
		22.08.86	Dechlor.	High		7.4							GT 100		
		23.08.86		High		7.5							25		
		24.08.86		Low		7.3							GT 100		
		27.08.86		High		7.5							GT 100		
		20.08.86	Chlor.	Low		7.3	9.15	0.5					GT 100		
		21.08.86				7.1	10.5	0.45					GT 100	20% mort. in 100%	
		22.08.86				6.9	9.5	0.65					GT 100		
		24.08.86				7.0	6.0	L 0.01					21		
		27.08.86				7.2	7.0	0.35					GT 100		
		20.08.86	Nonchlor.	High	CAS	7.4			Sg	0.8 g	L/S	96-h LC50	GT 100	10% mort. in 100%	6
		24.08.86				7.6							GT 100		
		20.08.86	Chlor.			7.3	3.5	0.68					GT 100		
		24.08.86				7.1	5.5	0.01					GT 100		
		20.08.86	Nonchlor.	Low		7.2							GT 100		
		24.08.86				7.0							GT 100		
		20.08.86	Chlor.			7.2	9.15	0.5					GT 100	10% mort. in 100%	
		24.08.86				7.0	1.3	0.0					GT 100		
Wingham	Maitland R.	07-08.77	Nonchlor.		WSP (CD; NA)		4.0		Sg	2.6 g	L/S	24 in 100%	GT 100	0/10 sample lethal	3
		12.77					3.0						GT 100	0% mortality	
		12.77					-						GT 100	0% mortality	
		01.78					6.0						GT 100	0% mortality	
		01.78					8.5						GT 100	0% mortality	
		02.78					9.5						GT 100	20% mortality	
		02.78					12						L 100	60% mortality	
		03.78					13						L 100	60% mortality	

TABLE A1: TOXICITY OF EFFLUENTS FROM ONTARIO STP's (cont'd)

Facility	Receiving Water	Sampling Date (m.y)	Effluent Type	STP Flow Rate	Treatment Process	pH	NH_3-N (mg/L)	TRC (mg/L)	Test Org.	Life Stage	Test Type	Response	LC50 (% effluent)	Comments	Ref.
Wingham (cont'd)	Maitland R.	03.78					16						L 100	90% mortality	3
		04.78					9.5						L 100	60% mortality	
		04.78					5.5						GT 100	0% mortality	
		05.78					4.2						GT 100	40% mortality	

Treatment Process:

WSP - Waste stabilization pond
CD - Continuous discharge
A - Aerated
NA - Nonaerated
CAS - Conventional activated sludge
AE - Extended aeration

Test Organism:

Sg - *Salmo gairdneri*
Dm - *Daphnia magna*
Cd - *Ceriodaphnia*

Test Type:

L - Laboratory
S - Static
CF - Continuous-flow

LC50:

GT - Greater than
L - Less than

References

1. Ontario Ministry of the Environment (1983).
2. Cairns and Conn (1979).
3. Metikosh et al. (1980).
4. Beak Consultants Limited (1986a).
5. Beak Consultants Limited (1986b).
6. Beak Consultants Limited (1986c).
7. Ontario Ministry of the Environment (1986).

TABLE A.. TOXICITY OF EFFLUENTS FROM OTHER CANADIAN STPs

Facility	Sampling Date	Test Organism	Test Type	Response	Effluent Type	Treatment Process	pH	NH_3-N	LC50 (% effluent)	Comments	Ref
Annacis Island STP (B.C.)	06.10.76	<u>Salmo gairdneri</u>	L/S	96-h LC50	Nonchlor.	Primary	6.8	28	45.5	Primary treatment did not reduce	1
	07.10.76						6.8	21	59.5	toxicity of raw waste; chlorination	
	08.10.76						7.0	20.5	75	increased toxicity and dechlorination	
	06.10.76				Chlor.		6.9	28	43	slightly reduced toxicity.	
	07.10.76						6.8	22	58		
	08.10.76						7.0	21.5	53		
	06.10.76				Dechlor.		6.8	21	51		
	07.10.76						6.8	20	75		
	08.10.76						6.9	20	78		
	09.76-12.76	<u>Oncorhynchus nerka</u>	L/CF	96-h LC50	Dechlor.		6.7	12.6	17	Dry weather	2
			L/S						35	Dry weather	
			L/CF						33	Wet weather	
			L/S						45	Wet weather	
	29.10.79		L/CF		Nonchlor.				22	Wet weather	3
	05.11.79								21	Dry weather	
	13.11.79								18	Dry weather	
	19.11.79								30	Wet weather	
	26.11.79								30	Wet weather	
	23.10.79		L/S						31	Dry weather	
	29.10.79								53	Wet weather	
	05.11.79								44	Dry weather	
	14.11.79								51	Dry weather	
	19.11.79								53	Wet weather	
	19.11.79								40	Wet weather	
	21.11.79								51	Wet weather	
	22.11.79								59	Wet weather	
	26.11.79								51	Wet weather	
	26.11.79								40	Wet weather	
	28.11.79								53	Wet weather	
	29.10.79								51	Wet weather, 24-h composite sample	
	05.11.79								32	Dry weather	
	13.11.79								33	Dry weather	
Cache Creek STP (B.C.)	31.08.76	<u>Salmo gairdneri</u>	L/S	96-h LC50	Nonchlor.	CAS	7.9	31	65	Toxicity probably related to NH_3	4
	01.09.76						7.7	30	74	levels; effluent TRC ranged [illegible] to	
	02.09.76						7.4	27	65	2.14 mg/L during a 24-h monitoring	
	03.09.76						7.6	36	52.5	program; toxicity not related to TRC	
	31.08.76				Chlor.		7.9	34	61		
	01.09.76						7.7	36	87		
	02.09.76						7.6	26	65		
	03.09.76						7.6	37	52.5		
Clinton STL (B.C.)	04.08.76	<u>Salmo gairdneri</u>	L/S	96-h LC50	Nonchlor.	WSP (NA)	8.1	1.5	GT 100		5
	04.08.76						8.2	1.3	GT 100		
Iona Island STP (B.C.)	17.08.76	<u>Salmo gairdneri</u>	L/S	96-h LC50	Nonchlor.	Primary	6.9	10	48	Primary treatment did not reduce	6
	18.08.76						6.9	11	86.5	toxicity; toxicity probably due to	
	17.08.76				Chlor.		7.1	10	44	NH_3; chlorine increased toxicity	
	18.08.76						7.1	11	58.5		
	1974	<u>Oncorhynchus nerka</u>	L/S	96-h LC50	Primary	Primary	7.0	10.7	40		7

TABLE A2: TOXICITY OF EFFLUENTS FROM OTHER CANADIAN STPs (cont'd)

Facility	Sampling Date	Test Organism	Test Type	Response	Effluent Type	Treatment Process	pH	NH_3-N	LC50 (% effluent)	Comments	Ref.
Lions Gate STP (B.C.)	1974	Oncorhynchus nerka	L/S	96-h LC50	Primary	Primary	7.1	16.1	28 & 33		7
Lulu Island STP (B.C.)	1974	Oncorhynchus nerka	L/S	96-h LC50	Primary	Primary	7.0	20.34	21		7
					Primary, dechlor.		7.0	20.34	23		
							7.0	20.34	5		
Mission PCC (B.C.)	06.09.76	Salmo gairdneri	L/S	96-h LC50	Nonchlor.	HRAS	7.0	10	GT 100	TRC of effluent ranged from ND to 1.80 mg/L; TRC of bioassay samples was ND	8
	07.09.76						7.2	15	GT 100		
	08.09.76						7.1	14	GT 100		
	09.09.76						7.1	18	GT 100		
	06.09.76				Chlor.		7.0	12	GT 100		
	07.09.76						7.3	22	GT 100		
	08.09.76						7.2	15	GT 100		
	09.09.76						7.1	18	GT 100		
City of Moosejaw ASP (Sask.)	30.11.76	Salmo gairdneri		96-h LC50	Chlor.	CSA	7.7	11.6	50-75		9
North Battleford ALS (Sask.)	01.12.76	Salmo gairdneri		96-h LC50	Chlor.	WSP (A)	7.8	16.5	34		9
Penticton WQCC (B.C.)	20.07.76	Salmo gairdneri	L/S	96-h LC50	Nonchlor.	CAS	7.4	21	87	Effluent TRC ranged from 0.8 to 3.48 mg/L (av. = 1.8) during a 24-h monitoring program, but was ND on bioassays; NH_3 and metals probably contributors to toxicity	10
	21.07.76						7.6	26	99		
	22.07.76						7.5	22	78		
	23.07.76						7.5	27	87		
	20.07.76				Chlor.		7.4	21	51		
	21.07.76						7.5	23	L 32		
	22.07.76						7.6	17	31		
	23.07.76						7.4	24	49		
Prince George STP (B.C.)	14.09.76	Salmo gairdneri	L/S	96-h LC50	Nonchlor.	HRAS	6.3	5	GT 100	Effluent TRC was 0.1 to 1.52 mg/L during a 24-h monitoring program, but ND in bioassays	11
	15.09.76						7.4	17	GT 100		
	14.09.76				Chlor.		7.5	7	GT 100		
	15.09.76						7.2	10	GT 100		
Regina STP (Sask.)	29.08.77	Salmo gairdneri	L/S	24-h LC50	Alum clarifier effluent	WSP (A)	7.11	23.4	GT 100	Unionized NH_3 probably greatest cause of lethality; alum and lime clarifiers are tertiary treatment systems operated in parallel after effluent chlorination	12
	06.09.77						6.83	9.2	GT 100		
	14.09.77						6.75	31.7	GT 100		
	22.09.77						6.93	22.6	L 100		
	02.11.77			96-h LC50			6.61	8.3	GT 100		
	14.11.77						6.75	23.5	GT 100		
	02.12.77						6.77	33.9	GT 100		
	06.12.77						7.14	30.4	GT 100		
	13.12.77						7.01	19.5	L 100		

Facility	Sampling Date	Test Organism	Test Type	Response	Effluent Type	Treatment Process	pH	NH_3-N	LC50 (% effluent)	Comments	Ref.
Regina STP (Sask.) (cont'd)	23.08.77	Salmo gairdneri	L/S	24-h LC50	Unneutralized		11.89	17.5	L 100		
	29.08.77				lime clarifier		11.74	21.4	L 100		
	06.09.77				effluent		11.79	8.5	L 100		
	14.09.77						12.13	27.0	L 100		
	22.09.77						12.14	23.2	L 100		
	03.10.77						11.91	13.4	L 100		
	02.11.77			96-h LC50			11.57	8.3	L 100		
	14.11.77						11.58	12.3	L 10		
	02.12.77						11.14	29.5	L 100		
	06.12.77						11.54	26.2	L 100		
	13.12.77						11.28	28.9	L 100		
	23.08.77			24-h LC50	Neutralized	WSP (A)	9.27	17.5	L 100		
	23.08.77				lime clarifier		8.51	17.5	L 100		
	03.10.77				effluent		5.82	13.4	GT 100		
	29.08.77				Unneutralized		9.86	20.2	L 100		
	06.09.77				combined		10.44	7.3	L 100		
	14.09.77				effluent		9.76	28.1	L 100		
	22.09.77						9.55	21.9	L100		
	02.11.77			96-h LC50			9.38	8.3	L 100		
	22.11.77						9.22	31.0	19		
	02.12.77						8.96	34.4	L 100		
	06.12.77						8.87	28.9	L 100		
	13.12.77						8.60	29.9	L 100		
	06.09.77			24-h LC50	Combined		8.56	-	GT 100		
	14.09.77				effluent		8.31	-	GT 100		
	22.09.77				neutralized		8.51	-	L 100		
	02.11.77			96-h LC50			7.58	8.3	GT 100		
	22.11.77						8.00	31.0	73-100		
	02.12.77						8.20	34.4	L 100		
	06.12.77						7.63	28.9	GT 100		
	13.12.77						8.38	29.9	L 100		
Saskatoon PTP (Sask.)	01.12.76	Salmo gairdneri		96-h LC50	Nonchlor.	Primary	7.6	10.5	50-75		9
	01.12.76						7.5	11.2	50-75		
Williams Lake (B.C.)	11.08.76	Salmo gairdneri	L/S	96-h LC50	Nonchlor.	WSP (A)	8.5	0.12	GT 100	Chlorinated effluent had very low (L 0.3 mg/L) or ND TRC levels	5
	12.08.76						8.3	0.20	GT 100		
	11.08.76				Chlor.		8.5	0.12	GT 100		
	12.08.76						8.3	0.17	GT 100		
Winnipeg, South End WPCC (Manitoba)	11.08.77	Salmo gairdneri	L/S	24-h LC50	Nonchlor.	EA	7.0	16.9	GT 100	NH_3 appeared to be major cause of toxicity	13
	17.08.77						7.1	1.7	GT 100		
	25.08.77						7.3	19.7	GT 100		
	02.09.77						7.5	15.7	GT 100		
	12.09.77						7.6	14.3	GT 100		
	20.09.77						7.1	19.1	GT 100		
	05.10.77			96-h LC50			7.2	16.8	L 100		
	12.10.77						7.3	18.0	89		
	26.10.77						7.2	20.7	L 100		
	10.11.77						7.3	18.7	L 80		
	13.12.77						7.8	23.7	L 100		

TABLE A2: TOXICITY OF EFFLUENTS FROM OTHER CANADIAN STPs (cont'd)

Facility	Sampling Date	Test Organism	Test Type	Response	Effluent Type	Treatment Process	pH	NH_3-N	LC50 (% effluent)	Comments	Ref.
Winnipeg, North End STP (Manitoba)	25.07.74	Salmo gairdneri	L/CF	96-h LC50	Chlor.	Secondary			70.9		14
			L/S						62.4		
	30.07.74		L/CF						67.7		
			L/S						55.8		
	04.08.74		L/CF						L 52.2		
			L/S						L 52.2		
			L/S		Nonchlor.				57.6		
		Hyalella azteca	L/CF		Chlor.				53.5		
		Daphnia pulex							L 31.6		
		Orconectes virilis							69.6		
	30.09.74	Salmo gairdneri	L/CF						L 52.2		
			L/S						17.3		
			L/S		Nonchlor.				68.9		
		Hyalella azteca	L/S		Chlor.				16.7		
	07.10.74	Salmo gairdneri	L/CF						L 15.3		
			L/S						L 15.3		
		Ictalurus melas							L 15.3		
		Hyalella azteca	L/CF						20.9		
	28.11.74	Salmo gairdneri	L/S		Nonchlor.				88.5		
		Ictalurus melas							GT 100		
	07.03.75	Salmo gairdneri	L/S	48-h LC50	Nonchlor.	Secondary			61	NH_3 ranged from 17.9 to 20.3 mg/L and pH was 7.2 to 7.8	15
	07.03.75								60		
	20.11.75			96-h LC50					62		
	20.11.75			48-h LC50					61		
	20.11.75								78		
	15.01.76			96-h LC50					74		
	15.01.76			48-h LC50					76		
	15.01.76								75		
	07.03.75		L/CF	96-h LC50					97		
	20.11.75								GT 100		
	15.01.76								95		
	07.03.75								75		
	20.11.75								GT 100		
	15.01.76								92		
	07.03.75	Coregonus clupeaformis	L/S	48-h LC50					51		
	20.11.75			96-h LC50					43		
	20.11.75								52		
	15.01.76								63		
	20.11.75	Salmo namaycush							72		
	15.01.76								92		
	20.11.75	Salvelinus alpinus							100		
	15.01.76								GT 100		
	07.03.75	Gammarus lacustris	L/CF						GT 100		
	20.11.75								GT 100		
	01.12.76								GT 100		
	07.03.75	Daphnia pulex							GT 100		
	20.11.75	Daphnia magna							GT 100		
	15.01.76								GT 100		
City of Yorkton EAP (Sask.)	30.11.76	Salmo gairdneri		96-h LC50	Final	EA	8.0	14.5	28		9

TABLE A2. TOXICITY OF EFFLUENTS FROM OTHER CANADIAN STPs (cont'd)

Test Type

L - laboratory test
S - static
CF - continuous-flow

Treatment Process

CAS - conventional activated sludge
WSP - waste stabilization pond
NA - non-aerated
A - aerated
HRAS - high rate activated sludge
EA - extended aeration

References

1. Higgs (1977a)
2. Servizi et al. (1978)
3. EPS (1979)
4. Higgs (1977f)
5. Higgs (1977g)
6. Higgs (1977c)
7. Martens and Servizi (1976)
8. Higgs (1977d)
9. Spink et al. (1977)
10. Higgs (1977e)
11. Higgs (1977b)
12. Spink and Thackeray (1979a)
13. Spink and Thackeray (1979b)
14. Clarke et al. (1977)
15. Alexander et al. (1977)

APPENDIX B

Dechlorination Methods

APPENDIX B: DECHLORINATION METHODS

The following information is summarized from Snoeyink and Suidan (1975).

Dechlorination with Sulphur Compounds

The use of sulphur compounds is the most common procedure employed to eliminate or reduce chlorine residual. Sulphur dioxide is most common procedure employed to eliminate or reduce chlorine residual. Sulphur dioxide is most common, and is added as a gas to water forming sulphurous acid (H_2SO_3). The acid partly ionizes to HSO_3^- and SO_3^{2-}, the degree of which is dependent on pH. Sodium bisulphite ($NaHSO_3$) and sodium sulphite (Na_2SO_3) are alternative sources for S (+ IV) required for dechlorination.

The SO_2 reaction in chlorinated water produces as follows:

$$SO_2 + H_2O + HOCl \longrightarrow 3H^+ + SO_4^{2-} + Cl^-, \tag{1}$$

with free chlorine (hypochlorous acid)

and $$SO_2 + 2H_2O + NH_2Cl \longrightarrow NH_4^+ + 2H^+ + SO_4^{2-} + Cl^-, \tag{2}$$

with monochloramine

These reactions occur almost instantaneously. A reaction similar to (2) occurs with dichloramine, nitrogen trichloride and poly-N-chlor compounds. It is noteworthy that the chloramine-N is reconverted to ammonia.

The S (+ IV) will also react with DO and may necessitate reaeration:

$$O_2 + 2SO_2 + 2H_2O \longrightarrow 4H^+ + 2SO_4^{2-} \tag{3}$$

Sodium thiosulphate reacts more slowly with residual chlorine than S (+ IV) compounds. Several stoichiometric reactions have been proposed (Equations 4 to 6), but the exact nature of thiosulphate-chlorine interactions is not well-defined:

$$2\ Na_2S_2O_3 + H^+ + HOCl \longrightarrow S_4O_6^{2-} + 4Na^+ + Cl^- + H_2O \tag{4}$$

$$Na_2S_2O_3 + 4HOCl + H_2O \rightarrow 6H^+ + 2SO_4^{2-} + 4Cl^- + 2Na^+ \quad (5)$$

$$Na_2S_2O_3 + HOCl \rightarrow 2Na^+ + SO_4^{2-} + S + H^+ + Cl^- \quad (6)$$

Dechlorination with Hydrogen Peroxide

Hydrogen peroxide has not been used extensively for dechlorination, but the following reaction is thought to take place:

$$HOCl + H_2O_2 \rightarrow O_2\,(aq) + H^+ + Cl^- + H_2O \quad (7)$$

The production of O_2 means reaeration would not be necessary. A problem with H_2O_2 is the possibility that it will be reduced by organic matter.

APPENDIX C

Concentrations of Contaminants in
Canadian STP Effluents

TABLE C1: CONCENTRATIONS OF INORGANICS IN GALT SEWAGE TREATMENT PLANT EFFLUENT (ug/L)

Sample Date	pH		Total NH_3-N		Cd		Cr		Cu		Ni		Pb		Zn	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
High Loading																
30.09.86[c]	8.58	7.32			1	1	53	19	100	21	27	28	10	5	146	46
01.10.86[d]	7.50	7.20			4	2	168	24	129	30	46	22	15	5	413	63
02.10.86	8.35	7.40			4	2	69	27	130	47	27	105	50	5	181	57
03.10.86	7.65	7.55			3	2	94	44	161	65	51	85	15	5	477	60
04.10.86	7.55	7.35			4	2	34	26	133	37	20	29	5	5	165	55
05.10.86[c]	7.70	7.50			1	1	22	23	111	34	16	20	10	5	145	43
06.10.86[d]	7.90	7.50			7	2	70	28	171	52	60	19	25	5	376	75
07.10.86	7.75	7.60		14.4	2	2	63	30	115	45	117	27	5	5	271	86
08.10.86[a,b]					6	4	88	32	129	66	30	73	20	5	203	68
Low Loading																
01.10.86	7.60	7.20		14.6	2	2	23	19	49	48	18	29	5	5	81	51
02.10.86	7.50	7.50	5.8	11.3	3	1	35	25	55	37	29	162	10	5	92	60
03.10.86	8.30	7.60		11.3	3	3	33	39	66	69	19	123	5	5	78	95
04.10.86	7.80	7.60		10.9	2	2	25	32	63	44	16	36	5	5	71	80
05.10.86	7.55	7.60		12.6	2	2	22	26	46	32	17	25	5	5	83	75
06.10.86[b]	7.40	7.50		15.0	2	2	34	27	48	38	24	28	10	10	72	84
07.10.86	7.50	7.70		12.9	2	11	82		149	32	41	27	15	5	223	189
08.10.86	7.50	7.52		12.2	20	5	252	35	112	80	41	100	5	5	119	132

[a] Non-chlorinated and [b] chlorinated effluent sample toxic to *Daphnia magna*.

[c] Influent sample lethal to *Daphnia magna*

[d] Influent sample lethal to *Salmo gairdneri*

TABLE C2: CONCENTRATIONS OF INORGANICS IN WATERLOO SEWAGE TREATMENT PLANT EFFLUENTS (ug/L)*

Date	pH	P		P(filt.)		Cd		Cr		Cu		Ni		Pb		Zn	
		In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
High Loading																	
02.07.86	7.2	7,070	820	3,900	770	4	4	74	20	118	13	24	17	105	5	339	55
04.07.86	7.2	10,500	850	3,690	310	5	4	58	25	141	7	26	20	30	5	163	71
05.07.86	7.5	6,970	990	4,000	380	6	5	33	26	105	9	22	25	5	5	138	85
06.07.86	7.4	6,510	1,070	3,380	500	4	5	29	21	93	13	20	22	10	5	88	43
08.07.86	8.0	7,210	1,930	3,850	1,380	6	6	53	35	110	17	41	41	15	5	156	83
09.07.86	7.9	6,930	750	3,840	230	4	4	58	19	149	14	26	23	35	5	153	87
10.07.86	7.5	7,290	710	4,000	190	4	4	43	27	156	12	23	23	30	5	227	67
Low Loading																	
03.07.86	7.0	2,630	930	1,080	540	3	4	37	29	77	10	20	23	10	10	81	109
04.07.86	7.0	7,800	800	2,000	500	3	5	65	64	50	13	19	25	5	5	110	111
05.07.86	7.5	3,390	1,100	1,850	500	5	4	32	22	55	14	24	27	10	5	69	104
06.07.86	7.3	3,210	1,000	1,540	540	6	6	29	21	46	13	21	23	5	5	51	50
09.07.86	7.4	3,030	1,030	620	380	6	5	38	29	115	15	25	27	70	70	143	77
10.07.86	7.5	3,140	830	620	270	4	3	29	24	82	11	19	24	5	5	112	79

* No samples were acutely lethal to Daphnia magna nor Salmo gairdneri.

TABLE C3: CONCENTRATIONS OF INORGANICS IN WELLAND SEWAGE TREATMENT PLANT EFFLUENTS

Sample Date	P (mg/L)		P (filt.) (mg/L)		Cd (ug/L)		Cr (ug/L)		Cu (ug/L)		Ni (ug/L)		Pb (ug/L)		Zn (ug/L)	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
High Load																
19.08.86	2.49	0.92	1.33	0.47	3	3	11	10	19	5	14	17	5	5	37	25
20.08.86[c]	3.66	0.94	2.00	0.53	1	1	9	8	22	7	7	11	5	5	66	28
22.08.86[b]	2.09	0.80	1.20	0.40	5	4	20	17	17	11	16	18	5	5	42	20
23.08.86[b]	2.85	0.91	2.13	0.57	4	3	13	10	19	4	14	16	5	5	43	20
24.08.86[c,d]	3.51	0.85	2.00	0.55	3	2	14	8	35	4	15	12	5	5	52	17
27.08.86[b]	2.65	0.56	1.47	0.33	2	3	12	8	26	4	14	15	5	5	58	14
Low Load																
20.08.86[c]	3.44	0.87	2.13	0.53	3	2	13	6	22	3	12	12	5	5	29	36
21.08.86	3.45	0.92	1.87	0.67	3	1	13	8	17	7	14	9	5	5	39	23
22.08.86	2.92	0.86	1.73	0.53	3	3	23	9	19	6	20	13	5	5	36	25
24.08.86[b,c]	5.74	0.81	2.27	0.53	3	2	21	8	93	6	23	11	5	5	185	22
27.08.86	1.74	0.69	0.93	0.37	2	2	12	6	18	4	12	11	10	5	65	14

[a] Non-chlorinated and [b] chlorinated sample toxic to Daphnia magna.

[c] Influent sample toxic to Salmo gairdneri.

[d] Influent sample toxic to Daphnia magna.

TABLE C4: METAL LEVELS DETECTED IN FINAL EFFLUENTS OF CANADIAN STPs

STP	Date	Cu	Fe	Ni	Pb	Zn	Al	Cd	Mn	Cr	Hg	CN	Process
Annacis Island	06.10.76	0.14	0.7	L 0.05	0.02	0.16	L 0.3	L 0.01	0.09	0.03	L 0.20	L 0.03	Primary
	07.10.76	0.06	0.80	L 0.05	L 0.02	0.16	L 0.3	L 0.01	0.08	0.03	0.21	0.04	
	08.10.76	0.05	0.78	L 0.05	L 0.02	0.15	L 0.3	L 0.01	0.09	0.03	0.21	0.03	
	06.10.76	0.02	1.4	L 0.05	0.02	0.12	L 0.3	L 0.01	0.09	0.03	0.21	0.06	
	07.10.76	0.07	1.3	L 0.05	L 0.02	0.09	L 0.3	L 0.01	0.10	0.03	0.25	0.07	
	08.10.76	0.05	1.4	L 0.05	L 0.02	0.10	L 0.3	L 0.01	0.09	0.02	0.25	0.06	
	06.10.76	0.13	1.4	L 0.05	L 0.02	0.16	L 0.3	L 0.01	0.08	0.03	L 0.2	0.04	
	07.10.76	0.14	1.4	L 0.05	L 0.02	0.16	L 0.3	L 0.01	0.09	0.02	L 0.2	0.04	
	08.10.76	0.15	1.4	L 0.05	L 0.02	0.15	L 0.3	L 0.01	0.09	0.03	L 0.2	0.06	
Cache Creek	31.08.76	L 0.01	0.19	L 0.05	L 0.02	0.28	L 0.3	L 0.01	0.05		0.4	L 0.03	CAS
	01.09.76	L 0.01	0.16	L 0.05	L 0.02	0.04	L 0.3	L 0.01	0.05	L 0.02	1.3	L 0.03	
	02.09.76	L 0.01	0.15	L 0.05	L 0.02	0.05	L 0.3	L 0.01	0.04	L 0.02	0.2	L 0.03	
	03.09.76	0.01	0.14	L 0.05	L 0.02	0.02	L 0.3	L 0.01	0.05	L 0.02	0.63	L 0.03	
	31.08.76	0.07	0.21	L 0.05	L 0.02	0.14	L 0.3	L 0.01	0.04	L 0.02	L 0.2	L 0.03	
	01.09.76	L 0.01	0.16	L 0.05	L 0.02	0.06	L 0.3	L 0.01	0.04	L 0.02	L 0.2	L 0.03	
	02.09.76	L 0.01	0.14	L 0.05	L 0.02	0.02	L 0.3	L 0.01	0.04	L 0.02	L 0.2	L 0.03	
	03.09.76	0.01	0.12	L 0.05	L 0.02	0.04	L 0.3	L 0.01	0.04	L 0.02	L 0.2	L 0.03	
City of Moosejaw ASP	30.11.76	0.02	0.57	L 0.02	L 0.1	0.056	L 0.5	L 0.014	0.20	L 0.015	L 0.20	-	CAS
City of Yorkton EAP	30.11.76	0.06	0.95	L 0.02	L 0.1	0.126	L 0.5	L 0.014	0.56	L 0.015	L 0.20	-	EA
Clinton STL	04.08.76	L 0.01	0.08	L 0.05	L 0.02	0.06	L 0.3	L 0.01	L 0.03	L 0.02	L 0.2	L 0.03	Lagoon
	04.08.76	0.01	0.04	L 0.05	L 0.02	0.03	L 0.3	L 0.01	0.03	L 0.02	L 0.2	-	
Iona Island	1974	0.10	0.53	L 0.1	L 0.02	0.09		L 0.01	L 0.06	L 0.08	L 0.8	L 0.03	Primary
	17.08.76	0.03	0.33	L 0.05	0.03	-	L 0.3	L 0.1	0.04	0.02	L 0.20	L 0.03	
	18.08.76	0.02	0.52	L 0.05	0.02	0.17	L 0.3	L 0.1	0.06	0.02	0.20	0.05	
	17.08.76	0.07	0.29	L 0.05	L 0.02	-	L 0.3	L 0.1	0.04	L 0.02	L 0.02	0.05	
	18.08.76	0.11	0.38	L 0.05	L 0.02	0.14	L 0.3	L 0.1	0.06	L 0.02	L 0.02	0.05	
Lions Gate	1974	0.18	0.81	L 0.1	0.02	0.10		L 0.03	0.03	L 0.03	L 0.8	L 0.03	Primary
Lulu Island	1974	0.15	2.3		0.04	0.20		0.01	0.1	0.11		0.11	Primary
Mission PCC	06.09.76	0.02	0.33	L 0.05	0.05	0.40	L 0.3	L 0.01	0.05	0.03	0.27	L 0.03	HRAS
	07.09.76	0.02	0.19	L 0.05	L 0.02	0.41	L 0.3	L 0.01	0.04	0.02	0.28	L 0.03	
	08.09.76	0.01	0.24	L 0.05	L 0.02	0.10	L 0.3	L 0.01	0.07	L 0.02	0.60	L 0.03	
	09.09.76	0.02	0.27	L 0.05	L 0.02	0.04	L 0.3	L 0.01	0.04	L 0.02	0.37	L 0.03	
	06.09.76	0.01	0.37	L 0.05	L 0.02	0.29	L 0.3	L 0.01	0.05	0.04	0.40	L 0.03	
	07.09.76	0.01	0.11	L 0.05	L 0.02	0.26	L 0.3	L 0.01	L 0.03	L 0.02	0.23	L 0.03	
	08.09.76	0.02	0.29	L 0.05	L 0.02	0.29	L 0.3	L 0.01	0.04	L 0.02	0.28	L 0.03	
	09.09.76	0.01	0.26	L 0.05	L 0.02	0.06	L 0.3	L 0.01	0.06	L 0.02	0.37	L 0.03	
North Battleford ALS	01.12.76	0.09	0.70	L 0.02	L 0.1	0.085	L 0.5	L 0.014	0.58	L 0.015	L 0.20	-	Lagoon
North End STP, Winnipeg	07.03.75	0.068	0.290	0.038	L 0.05	0.230		L 0.005		L 0.005			Secondary
	20.11.75	0.007	0.063	0.033	L 0.002	0.072		0.0		0.046			
Penticton WQCC	20.07.76	0.03	0.35	L 0.05	L 0.02	0.19	L 0.3	L 0.01	0.09	L 0.02	L 0.2	L 0.03	CAS
	21.07.76	0.03	0.10	L 0.05	L 0.02	0.10	L 0.3	L 0.01	0.05	L 0.02	1.9	L 0.03	
	22.07.76	0.03	0.15	L 0.05	L 0.02	0.20	L 0.3	L 0.01	0.06	L 0.02	L 0.2	L 0.03	
	23.07.76	0.02	0.12	L 0.05	L 0.02	0.18	L 0.3	L 0.01	0.05	L 0.02	0.2	L 0.03	
	20.07.76	0.03	0.46	L 0.05	L 0.02	0.18	L 0.3	L 0.01	0.09	L 0.02	L 0.02	0.05	
	21.07.76	0.01	0.16	L 0.05	L 0.02	0.10	L 0.3	L 0.01	0.07	L 0.02	L 0.02	0.03	
	22.07.76	0.02	0.19	L 0.05	L 0.02	0.12	L 0.3	L 0.01	0.08	L 0.02	L 0.02	0.07	
	23.07.76	0.02	0.16	L 0.05	L 0.02	0.37	L 0.3	L 0.01	0.07	L 0.02	L 0.02	0.05	
Prince George	14.09.76	0.04	0.15	L 0.05	L 0.02	0.08	L 0.3	L 0.01	0.06	L 0.02	L 0.2	0.08	HRAS
	15.09.76	0.03	0.12	L 0.05	L 0.02	0.06	L 0.3	L 0.01	0.06	L 0.02	L 0.2	0.08	
	14.09.76	0.06	0.14	L 0.05	L 0.02	0.08	L 0.3	L 0.01	0.07	L 0.02	0.2	0.08	
	15.09.76	0.04	0.11	L 0.05	L 0.02	0.06	L 0.3	L 0.01	0.05	L 0.02	L 0.2	0.06	
Saskatoon PTP	01.12.76	0.03	0.33	L 0.02	L 0.1	0.048	L 0.5	L 0.014	0.07	L 0.015	L 0.20	-	Primary
	01.12.76	0.04	0.38	L 0.02	L 0.1	0.07	L 0.5	L 0.014	0.08	L 0.015	L 0.20	-	Primary
Williams Lake	11.08.76	0.02	0.04	L 0.05	L 0.02	0.12	L 0.3	L 0.01	L 0.03	L 0.02	L 0.2	0.08	Lagoon
	12.08.76	0.03	L 0.03	L 0.05	L 0.02	-	L 0.3	L 0.01	L 0.03	L 0.02	L 0.2	0.07	
	11.08.76	0.02	0.05	L 0.05	L 0.02	0.10	L 0.3	L 0.01	L 0.03	L 0.02	L 0.2	0.08	
	12.08.76	0.02	0.08	L 0.05	L 0.02	-	L 0.3	L 0.01	L 0.03	L 0.02	L 0.2	0.08	

CAS - conventional activated sludge.
EA - extended aeration.
HRAS - high rate activated sludge.

TABLE C5: CONCENTRATIONS OF ORGANICS IN GALT SEWAGE TREATMENT PLANT EFFLUENT (ug/L)

Sample Date	Phenolics (4-AAP)	Chloroform In	Chloroform Out	1,1,1-Trichloroethane In	1,1,1-Trichloroethane Out	Benzene In	Benzene Out	Trichloro-ethylene In	Trichloro-ethylene Out	Toluene In	Toluene Out	Tetrachloro-ethylene In	Tetrachloro-ethylene Out	Ethyl Benzene In	Ethyl Benzene Out	p & m-Xylene In	p & m-Xylene Out	1,4-Dichloro-benzene In	1,4-Dichloro-benzene Out
High Flow																			
30.09.86[c]	1.0	2.01	0.50	3.56	2.30	0.97	0.25	3.59	1.00	0.25	0.25	12.23	8.75	218.98	0.56	1,146.77	1.38	4.51	2.43
01.10.86[d]	5.0	2.60	1.00	4.99	1.59	0.87	0.25	4.98	1.00	4.21	0.25	25.62	6.02	1.36	0.25	6.51	0.25	6.28	1.16
02.10.86	7.8	2.27	1.00	5.67	1.54	1.06	0.25	4.44	1.00	3.76	0.25	22.37	5.07	50.86	0.25	302.63	0.25	5.46	1.14
03.10.86	3.4	1.95	1.00	6.58	2.17	0.75	0.25	4.79	0.50	3.35	0.25	5.39	3.17	2.62	0.25	12.84	0.25	5.96	1.07
04.10.86	2.4	3.14	1.00	6.01	3.29	0.90	0.25	5.20	1.00	2.79	0.25	6.16	2.18	0.66	0.25	3.04	0.25	4.96	1.00
05.10.86[c]	3.2	1.21	0.50	6.03	1.00	0.91	0.25	5.37	0.50	3.56	0.25	1.14	1.00	0.58	0.25	2.75	0.25	5.35	1.00
06.10.86[d]	5.2	1.51	0.50	5.70	1.44	0.56	0.25	4.39	1.00	4.62	0.25	8.98	0.50	0.25	0.25	8.98	0.25	4.22	1.05
07.10.86	4.6	1.47	0.50	4.64	1.41	0.50	0.25	4.99	1.00	2.60	0.25	8.26	0.50	1.17	0.25	5.57	0.25	5.53	1.35
08.10.86[a,b]	8.0	48.14	0.50	5.13	1.54	0.50	0.25	5.49	1.00	5.33	0.25	3.17	1.00	0.97	0.25	4.98	0.68	5.05	1.18
Low Flow																			
01.10.86	2.8	0.50	1.00	3.70	2.38	0.61	0.253	3.42	1.00	1.84	0.25	5.15	35.03	0.59	0.50	3.19	1.68	2.23	1.77
02.10.86	1.0	1.16	1,00	5.56	2.25	1.00	0.253	5.23	1.00	3.48	0.25	4.33	17.63	0.82	0.25	5.11	0.25	3.33	1.36
03.10.86	6.8	0.50	1.00	3.93	2.48	0.53	0.253	3.04	0.50	1.48	0.25	1.62	13.13	0.50	0.25	1.81	0.25	2.03	1.27
04.10.86	6.8	1.02	1.00	5.74	2.64	1.04	0.25	5.09	1.00	3.16	0.25	3.30	5.56	0.92	0.50	4.84	0.50	3.42	1.20
05.10.86	2.4	1.00	1.00	5.94	1.90	0.88	0.25	5.18	1.00	5.32	0.25	2.42	1.08	09.50	0.25	2.38	0.25	3.60	1.33
06.10.86[b]	3.0	4.38	0.50	5.56	1.90	0.80	0.25	5.07	1.00	24.87	0.25	19.36	1.00	1.49	0.25	7.39	0.25	5.10	1.26
07.10.86	6.8	2.47	0.50	5.94	1.56	0.56	0.25	5.21	1.09	2.40	0.25	2.21	1.00	0.84	0.25	4.73	1.20	3.29	1.57
08.10.86	4.0	1.00	0.50	1.54	1.92	0.25	0.25	1.03	1.00	0.50	0.25	0.50	2.21	0.25	0.50	20.50	4.33	1.00	1.33

[a] Non-chlorinated and [b] chlorinated sample caused acute lethality to *Daphnia magna*

[c] Influent sample lethal to *Daphnia magna*

[d] Influent sample lethal to *Salmo gairdneri*

TABLE C6: CONCENTRATIONS OF ORGANICS IN WATERLOO SEWAGE TREATMENT PLANT EFFLUENT (ug/L)*

Sample Date	Phenolics		Benzene		Chloroform		1,4-Dichlorobenzene		1,1,1-Trichloroethane		Trichloro-ethylene		Toluene		P&M-Xylene	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
High Loading																
02.07.86		3.7	1.24	0.50	1.03	1.96	5.92	0.50	0.50	1.00	1.68	0.50	4.03	0.25	118.86	0.25
04.07.86	14.3	1.1	0.68	0.25	1.98	0.50	0.50	0.50	1.00	0.50	1.83	0.50	2.73	0.50	302.4	0.25
05.07.86	35.9	6.9	1.33	0.50	9.49	1.84	8.73	1.00	0.50	1.06	1.00	0.50	2.86	0.50	7.74	0.50
06.07.86		1.3	0.61	0.25	0.50	0.50	6.60	1.00	0.50	0.50	1.00	0.50	1.35	0.25	2.77	0.25
08.07.86	22.8	4.0	0.59	0.25	5.75	1.63	1.82	0.50	2.98	0.50	2.89	0.50	4.44	1.03	17.14	0.50
09.07.86	34.4	1.5	0.80	0.25	5.41	0.50	0.50	0.50	1.48	1.04	1.60	0.50	2.76	0.25	14.23	0.25
10.07.86		2.2	1.32	0.25	2.21	1.80	0.50	0.50	1.00	1.70	1.35	0.50	3.41	0.25	4.76	0.25
Low Loading																
03.07.86	15.0	3.7	1.23	0.25	0.50	0.50	1.13	1.00	0.50	1.04	0.50	0.50	6.69	0.50	7.23	0.50
04.07.86	7.4	2.8	0.50	0.25	1.98	0.50	0.50	1.00	2.39	1.28	0.50	0.50	1.06	0.25	5.06	0.25
05.07.86	1.0	3.3	1.06	0.25	2.48	0.50	1.00	1.00	3.20	0.50	0.50	0.50	5.91	0.25	3.26	0.50
06.07.86	3.3	1.7	1.15	0.25	1.41	0.50	4.67	0.50	1.14	0.50	1.00	0.50	1.37	0.25	2.72	0.50
09.07.86	8.7	1.2	5.53	0.25	5.44	2.64	0.50	0.50	2.16	0.50	8.04	0.50	5.07	0.25	12.23	1.00
10.07.86	34.0	6.2	1.72	0.25	4.19	0.50	0.50	1.00	2.56	0.50	0.50	0.50	9.20	0.25	3.99	2.14

* No samples were acutely lethal to Daphnia magna nor Salmo gairdneri.

TABLE C7: CONCENTRATIONS OF ORGANICS IN WELLAND SEWAGE TREATMENT PLANT EFFLUENT (ug/L)

Sample Date	Phenolics	Chloroform		1,4-Dichlorobenzene		Trichloro-ethylene		Toluene		P&M-Xylene	
		In	Out	In	Out	In	Out	In	Out	In	Out
High Load											
19.08.86	3.4	6.67	1.00	1.93	1.00	1.00	0.50	0.50	0.25	0.25	0.25
20.08.86[c]	5.0	4.19	1.00	2.29	0.50	1.00	0.50	1.17	0.25	4.32	0.67
22.08.86[b]	3.4	3.33	1.00	2.56	1.00	0.50	0.50	0.25	0.25	0.25	0.25
23.08.86[b]	1.0	3.73	1.01	2.04	1.00	0.50	0.50	0.50	0.25	0.25	0.25
24.08.86[c,d]	2.4	5.73	1.14	2.32	1.00	0.50	0.50	0.95	0.25	0.50	0.25
27.08.86[b]	1.0	0.50	2.19	2.19	1.00	0.50	0.50	0.50	0.25	0.25	0.25
Low Load											
20.08.86[c]	5.0	2.75	1.00	1.58	1.00	0.50	0.50	0.63	0.25	0.25	0.25
21.08.86	2.4	4.71	1.00	1.87	0.50	1.00	0.50	1.54	0.25	0.25	0.25
22.08.86	8.8	3.40	1.00	2.30	2.10	1.00	0.50	0.63	0.25	0.25	0.25
24.08.86[b,c]	1.6	3.56	1.00	2.64	1.00	1.00	0.50	1.58	0.25	0.25	0.25
27.08.86	2.4	3.10	0.50	2.14	1.00	0.50	0.50	0.91	0.66	0.76	0.25

[a] Non-chlorinated and [b] chlorinated sample toxic to Daphnia magna.

[c] Influent sample toxic to Salmo gairdneri.

[d] Influent sample toxic to Daphnia magna.

APPENDIX D

Performance Evaluation for Ontario STPs
Based on Monthly Ammonia Data

LEVEL 1

STP's CATEGORIZED BY MONTHLY AMMONIA CONCENTRATIONS

TYPE OF PLANT	Mo/Yr EFF. NH3 >10 mg/L	BOD REMOVAL (Percent)	INDUSTRIAL COMPONENT	PLANT NAME	MOE REGION	OPERATING AUTHORITY	COMMENTS
LAGOONS	0	> 80%	DOMESTIC (INFLUENT BOD <125 mg/L)	HENSALL	SW	MOE	ANNUAL DISCHARGE; NH3 FREQUENCY >10 MG/L PRO-RATED
				NICKEL CENTRE (WAHN.)	NE	MUN	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				TILBURY N (STONEY POINT)	SW	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				ESSEX (N.E.)	SW	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				WIARTON	SW	MOE	
				SUNDRIDGE	NE	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				ATWOOD (RAINY RIVER)	NW	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				ANDERDON (EDGEWATER)	SW	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				DOVER	SW	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				CASSELMAN	SE	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				FORT ERIE (STEVENSVILLE)	WC	MUN	
				VANKLEEK HILL	SE	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				MATTAWA	NE	MOE	EXFILT. LAGOON: NH3 FREQUENCY > 10 MG/L PRO-RATED
				GOSFIELD N. (COTTAM)	SW	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				BELMONT	SW	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				THEDFORD	SW	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				SARNIA (BRIGHT'S GROVE)	SW	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				SOMBRA (PORT SOMBRA)	SW	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				PORT STANLEY	SW	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				CALDWELL (VERNER)	NE	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				ZURICH	SW	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				HAILEYBURY (N. COBALT)	NE	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				WATFORD	SW	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				PLANTAGENET	SE	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				ERNESTOWN (AMHERSTVIEW)	SE	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				NICKEL CENTER (GARSON)	NE	MUN	BOD REM. ASSUMED >80%; NH3 FREQUENCY > 10 MG/L PRO-RATED

NOTE: THE PERCENT INDUSTRIAL CONTRIBUTION FOR LAGOONS WAS BASED ON INFLUENT BOD CONCENTRATIONS

LEVEL 1

STP's CATEGORIZED BY MONTHLY AMMONIA CONCENTRATIONS

TYPE OF PLANT	Mo/Yr EFF. NH3 >10 mg/L	BOD REMOVAL (Percent)	INDUSTRIAL COMPONENT	PLANT NAME	MOE REGION	OPERATING AUTHORITY	COMMENTS
LAGOONS	0	> 80%	MINOR (INFLUENT BOD 126-250 mg/L)	RALEIGH (MERLIN)	SW	MOE	ANNUAL DISCHARGE; NH3 FREQUENCY >10 MG/L PRO-RATED
				ALEXANDRIA	SE	MOE	NH3 FREQUENCY > 10 MG/L PRO-RATED
				SOMBRA (PORT LAMBTON)	SW	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				ARRAN (TARA)	SW	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				MADOC	SE	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				AYLMER	SW	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				STRATHROY	SW	MUN	
				TILBURY WEST (PV COMBER)	SW	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				RIDGETOWN	SW	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				NORMANBY (NEUSTADT)	SW	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				MCGILLIVRAY (PARKHILL)	SW	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				BROCK (BEAVERTON)	C	MUN	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				ESSEX (S.W.)	SW	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				RUSSELL	SE	MOE	ANNUAL DISCHARGE; NH3 FREQUENCY >10 MG/L PRO-RATED
				STEPHEN (GRAND BEND)	SW	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				SCUGOG	C	MUN	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				BLANDFORD BLENHEIM	SW	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				DUTTON	SW	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				ST. ISIDORE DE PRESCOTT	SE	MOE	ANNUAL DISCHARGE; NH3 FREQUENCY >10 MG/L PRO-RATED ED
				BLENHEIM	SW	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				NORWICH	SW	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				WEBBWOOD	NE	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
			MAJOR (INFLUENT BOD) (> 250 MG/L)	MOORE (BRIGDEN)	SW	MOE	ANNUAL DISCHARGE; NH3 FREQUENCY >10 MG/L PRO-RATED
				MITCHELL	SW	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				TEMAGAMI	NE	MOE	BOD. REM. ASSUMED <80%; SEASON DISCH.; NH_3 FREQUENCY <10 mg/L PRO-RATED.
				KAPUSKASING (BRUNET).	NE	MUN	
				GRIMSBY (BIGGAR)	WC	MUN	

NOTE: THE PERCENT INDUSTRIAL CONTRIBUTION FOR LAGOONS WAS BASED ON INFLUENT BOD CONCENTRATIONS

LEVEL 1

STP's CATEGORIZED BY MONTHLY AMMONIA CONCENTRATIONS

TYPE OF PLANT	Mo/Yr EFF. NH3 >10 mg/L	BOD REMOVAL (Percent)	INDUSTRIAL COMPONENT	PLANT NAME	MOE REGION	OPERATING AUTHORITY	COMMENTS
LAGOONS	0	< 80%	DOMESTIC (INFLUENT BOD <125 MG/L)	LITTLE CURRENT	NE	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				DUNDALK	SW	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				THORNBURY	SW	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				TWEED	SE	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				LUCAN	SW	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				ASSIGINACK(MANITOWANING)	NE	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				WEST LORNE	SW	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				NANTICOKE (JARVIS)	WC	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				BROCK (CANNINGTON)	C	MUN	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
			MINOR	FOREST	SW	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
	1 TO 3	> 80%	DOMESTIC (INFLUENT BOD <125 MG/L)	CAPREOL	NE	MUN	NO DISC. TO SURF. WATER; NH_3 FREQUENCY>10 MG/L
				LAKEFIELD	C	MUN	
				BRIGHTON	C	MUN	
				SEAFORTH	SW	MOE	SEASONAL DISCHARGE; NH_3 FREQUENCY > 10 MG/L PRO-RATED
				NANTICOKE (WATERFORD)	WC	MOE	
				WESTPORT	SE	MOE	SEASONAL DISCHARGE; NH_3 FREQUENCY > 10 MG/L PRO-RATED
			MINOR (INFLUENT BOD) (126-250 MG/L)	ARTHUR	WC	MOE	SEASONAL DISCHARGE; NH_3 FREQUENCY > 10 MG/L PRO-RATED
				ROCKLAND	SE	MOE	NH3 FREQUENCY >10MG/L PRO-RATED
				WINGHAM	SW	MOE	
				WINCHESTER	SE	MOE	SEASONAL DISCHARGE; NH_3 FREQUENCY > 10 MG/L PRO-RATED
				ALMONTE	SE	MOE	SEASONAL DISCHARGE; NH_3 FREQUENCY > 10 MG/L PRO-RATED
				NIAGARA-ON-THE-LAKE	WC	MUN	
				LINDSAY	C	MUN	INDUSTRIAL COMPONENT BASED ON PROF. JUDGEMENT
		< 80%	DOMESTIC (INFLUENT BOD <125 MG/L)	ELMVALE	C	MUN	

NOTE: THE PERCENT INDUSTRIAL CONTRIBUTION FOR LAGOONS WAS BASED ON INFLUENT BOD CONCENTRATIONS

LEVEL 1

STP's CATEGORIZED BY MONTHLY AMMONIA CONCENTRATIONS

TYPE OF PLANT	Mo/Yr EFF. NH3 >10 mg/L	BOD REMOVAL (Percent)	INDUSTRIAL COMPONENT	PLANT NAME	MOE REGION	OPERATING AUTHORITY	COMMENTS
LAGOONS	4 to 6	> 80%	DOMESTIC (INFLUENT BOD <125 MG/L)	GANANOQUE	SE	MUN	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				EXETER	SW	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				WEST LINCOLN	WC	MUN	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				KINCARDINE	SW	MOE	
			MINOR	HARRISTON	WC	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				PERTH	SE	MUN	
			MAJOR	LISTOWEL	SW	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				RODNEY	SW	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				EAST ZORRA-TAVISTOCK	SW	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
		< 80%	DOMESTIC	CHESTERVILLE	SE	MOE	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
				ENGLEHART	NE	MOE	
			MINOR	DUNNVILLE (OSWEGO PARK)	WC	MOE	ANNUAL DISCHARGE; NH3 FREQUENCY >10 MG/L PRO-RATED
			MAJOR	STAYNER	C	MUN	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED
	10 to 12	< 80%	DOMESTIC	RAYSIDE-BALFOUR(CHELMS.)	NE	MUN	SEASONAL DISCHARGE; NH3 FREQUENCY > 10 MG/L PRO-RATED

NOTE: THE PERCENT INDUSTRIAL CONTRIBUTION FOR LAGOONS WAS BASED ON INFLUENT BOD CONCENTRATIONS

LEVEL 1
STP's CATEGORIZED BY MONTHLY AMMONIA CONCENTRATIONS

TYPE OF PLANT	Mo/Yr EFF. NH3 >10 mg/L	BOD REMOVAL (Percent)	INDUSTRIAL COMPONENT	PLANT NAME	MOE REGION	OPERATING AUTHORITY	COMMENTS
SECONDARY	0	> 80%	DOMESTIC < 5.0%	VAUGHAN	C	MUN	
				DYSART-ET-AL	C	MUN	
				WALDEN (LIVELY)	NE	MUN	
				UXBRIDGE	C	MUN	
				LONDON (OXFORD)	SW	MUN	
				PORT ELGIN	SW	MUN	NH3 FREQUENCY > 10 MG/L PRO-RATED
				ONAPING FALLS (ONAPING)	NE	MUN	INDUSTRIAL COMPONENT BASED ON PROF. JUDGEMENT
				ONAPING FALLS (LEVACK)	NE	MUN	INDUSTRIAL COMPONENT BASED ON PROF. JUDGEMENT
				PENETANGUISHENE	C	MUN	INDUSTRIAL COMPONENT BASED ON PROF. JUDGEMENT
				TIMMINS (WHITNEY)	NE	MUN	INDUSTRIAL COMPONENT BASED ON PROF. JUDGEMENT
				RAYSIDE-BALFOUR (CHELMS)	NE	MUN	INDUSTRIAL COMPONENT BASED ON PROF. JUDGEMENT
				ONAPING FALLS (DOWLING)	NE	MUN	INDUSTRIAL COMPONENT BASED ON PROF. JUDGEMENT
				GEORGINA (KESWICK)	C	MUN	INDUSTRIAL COMPONENT BASED ON PROF. JUDGEMENT
				NEPEAN (CARLTON)	SE	MUN	INDUSTRIAL COMPONENT BASED ON PROF. JUDGEMENT

LEVEL 1

STP's CATEGORIZED BY MONTHLY AMMONIA CONCENTRATIONS

TYPE OF PLANT	Mo/Yr EFF. NH3 >10 mg/L	BOD REMOVAL (Percent)	INDUSTRIAL COMPONENT	PLANT NAME	MOE REGION	OPERATING AUTHORITY	COMMENTS
SECONDARY	0	> 80%	MINOR 5.1 to 30%	GUELPH	WC	MUN	
				CRAMAHE	C	MUN	
				LONDON (GREENWAY)	SW	MUN	
				MOUNT FOREST	WC	MUN	
				MILTON	C	MUN	
				MUSKOKA LAKES (P. CARLING)	C	MUN	IND. COMP. BASED ON PROF. JUDG.; NH_3 FREQUENCY >10 mg/L PRO-RATED
				NEWCASTLE (GRAHAM CREEK)	C	MUN	NH_3 FREQUENCY <10 mg/L PRO-RATED
				ST. CATHARINES (WELLER)	WC	MUN	
				FLAMBOROUGH	WC	MUN	
				HANOVER	SW	MUN	
				ST. THOMAS	SW	MUN	INDUSTRIAL COMPONENT BASED ON PROF. JUDGEMENT
				CLINTON	SW	MUN	INDUSTRIAL COMPONENT BASED ON PROF. JUDGEMENT
				WELLAND	WC	MUN	INDUSTRIAL COMPONENT BASED ON PROF. JUDGEMENT
				RAYSIDE-BAYFOUR (AZILDA)	NE	MUN	
				GRIMSBY (BAKER ROAD)	WC	MUN	
				LONDON (ADELAIDE)	SW	MUN	
				LONDON (POTTERSBURG)	SW	MUN	
				WALDEN (MIKKOLA)	NE	MUN	
				WINDSOR (LITTLE)	SW	MUN	

LEVEL 1

STP's CATEGORIZED BY MONTHLY AMMONIA CONCENTRATIONS

TYPE OF PLANT	Mo/Yr EFF. NH3 >10 mg/L	BOD REMOVAL (Percent)	INDUSTRIAL COMPONENT	PLANT NAME	MOE REGION	OPERATING AUTHORITY	COMMENTS
SECONDARY	0	> 80%	MAJOR > 30%	WHITCHURCH-STOUFFVILLE	C	MUN	
				MISSISSAUGA (CLARKSON)	C	MOE	
				CHATHAM	SW	MUN	
				LONDON (VAUXHALL)	SW	MUN	
				DRYDEN	NW	MUN	
				ST. CATHARINES (DALHOUSIE)	WC	MUN	
				WOODSTOCK	SW	MUN	
				PORT HOPE	C	MUN	
				HALTON HILLS (GEORGETOWN)	C	MUN	
		< 80%	DOMESTIC	GEORGINA (SUTTON)	C	MUN	IND. COMP. BASED ON PROF. JUDG.; NH_3 FREQUENCY > 10mg/L PRO-RATED
				COCHRANE	NE	MUN	
			MINOR	COBOURG 2	C	MUN	INDUSTRIAL COMPONENT BASED ON PROF. JUDGEMENT

LEVEL 1

STP's CATEGORIZED BY MONTHLY AMMONIA CONCENTRATIONS

TYPE OF PLANT	Mo/Yr EFF. NH_3 >10 mg/L	BOD REMOVAL (Percent)	INDUSTRIAL COMPONENT	PLANT NAME	MOE REGION	OPERATING AUTHORITY	COMMENTS
SECONDARY	1 to 3	> 80%	DOMESTIC <5.0%	BRACEBRIDGE	C	MUN	INDUSTRIAL COMPONENT BASED ON PROF. JUDGEMENT
				HALDIMAND (CALEDONIA)	WC	MOE	
			MINOR 5.1 to 30%	CAMBRIDGE (PRESTON)	WC	MOE	
				WALKERTON	SW	MUN	
				WATERLOO	WC	MOE	
				KITCHENER	WC	MOE	INDUSTRIAL COMPONENT BASED ON PROF. JUDGEMENT
				ORILLIA	C	MUN	INDUSTRIAL COMPONENT BASED ON PROF. JUDGEMENT
				OSHAWA NO. 2	C	MUN	
				PETERBOROUGH	C	MUN	
				SUDBURY	NE	MUN	
			MAJOR > 30%	WHITBY (PRINGLE CR. 2)	C	MUN	
				OSHAWA NO. 1	C	MUN	
				MISSISSAUGA (LAKEVIEW)	C	MOE	
				NEWCASTLE (DARLINGTON)	C	MUN	
				METRO TORONTO (NORTH)	C	MUN	
				COBOURG NO. 1	C	MUN	
				GODERICH	SW	MUN	
				PT. COLBORNE (SEAWAY)	WC	MUN	
				PICKERING	C	MUN	
		< 80%	DOMESTIC < 5.0%	FT. ERIE (CRYSTAL BEACH)	WC	MUN	INDUSTRIAL COMPONENT BASED ON PROF. JUDGEMENT

LEVEL 1

STP's CATEGORIZED BY MONTHLY AMMONIA CONCENTRATIONS

TYPE OF PLANT	Mo/Yr EFF. NH_3 >10 mg/L	BOD REMOVAL (Percent)	INDUSTRIAL COMPONENT	PLANT NAME	MOE REGION	OPERATING AUTHORITY	COMMENTS
SECONDARY	4 to 6	> 80%	DOMESTIC	HALTON HILLS (ACTON)	C	MUN	
				NICKEL CENTRE (CONISTON)	NE	MUN	INDUSTRIAL COMPONENT BASED ON PROF. JUDGEMENT
			MINOR	HUNTSVILLE	C	MUN	INDUSTRIAL COMPONENT BASED ON PROF. JUDGEMENT
				OAKVILLE (SOUTHEAST)	C	MUN	INDUSTRIAL COMPONENT BASED ON PROF. JUDGEMENT
				WHITBY (PRINGLE CK. 1)	C	MUN	
				WHITBY (CORBETT CR)	C	MUN	
			MAJOR	MIDLAND	C	MUN	
				STRATFORD	SW	MOE	
		< 80%	MINOR	NEPEAN (WATTS CREEK)	SE	MUN	
				CAMBRIDGE (HESPELER)	WC	MOE	
			MAJOR	NIAGARA FALLS	WC	MUN	
	7 to 9	> 80%	DOMESTIC	GRAVENHURST	C	MUN	IND. COMP. BASED ON PROF. JUDG.: NH_3 FREQUENCY > 10mg/L PRO-RATED
				ELLIOT LAKE	NE	MUN	INDUSTRIAL COMPONENT BASED ON PROF. JUDGEMENT
			MINOR	BURLINGTON	C	MUN	
			MAJOR	METRO TORONTO (HUMBER)	C	MUN	
				CAMBRIDGE (GALT)	WC	MOE	
				OAKVILLE (SOUTHWEST)	C	MUN	NH_3 FREQUENCY > 10 mg/L PRO-RATED

LEVEL 1

STP's CATEGORIZED BY MONTHLY AMMONIA CONCENTRATIONS

TYPE OF PLANT	Mo/Yr EFF. NH_3 >10 mg/L	BOD REMOVAL (Percent)	INDUSTRIAL COMPONENT	PLANT NAME	MOE REGION	OPERATING AUTHORITY	COMMENTS
SECONDARY	10 to 12	> 80%	DOMESTIC	VALLEY EAST SIOUX LOOKOUT	NE NW	MUN MUN	INDUSTRIAL COMPONENT BASED ON PROF. JUDGEMENT
			MINOR	METRO TORONTO (MAIN)	C	MUN	
			MAJOR	METRO TORONTO (HIGHLAND) BARRIE HAMILTON	C C WC	MUN MUN MUN	
PRIMARY	0	< 80%	DOMESTIC	FORT ERIE (ANGER AVE.)	WC	MUN	INDUSTRIAL COMPONENT BASED ON PROF. JUDGEMENT
	4 to 6	< 80%	DOMESTIC	TIMMINS (MATTAGAMI)	NE	MUN	INDUSTRIAL COMPONENT BASED ON PROF. JUDGEMENT
			MAJOR	OTTAWA (GLOUCESTER GR. CR) WINDSOR (WESTERLY)	SE SW	MUN MUN	
	7 to 9	<80%	DOMESTIC	AMHERSTBURG	SW	MUN	INDUSTRIAL COMPONENT BASED ON PROF. JUDGEMENT
	10 to 12	<80%	DOMESTIC	RED ROCK	NW	MUN	INDUSTRIAL COMPONENT BASED ON PROF. JUDGEMENT

APPENDIX E

Performance Evaluation for Ontario STPs
Based on Annual Ammonia Data

LEVEL 2
STP's CATEGORIZED BY ANNUAL AMMONIA CONCENTRATIONS

TYPE OF PLANT	EFFLUENT AMMONIA CONC.	BOD REMOVAL (Percent)	INDUSTRIAL COMPONENT	PLANT NAME	MOE REGION	OPERATING AUTHORITY	COMMENTS
LAGOON	< 10 mg/L	> 80%	DOMESTIC (INFLUENT BOD < 125 mg/L)	KINGSVILLE	SW	MUN	
				NANTICOKE (TOWNSEND)	WC	MOE	NO DISCHARGE
				COULBOURN (MUNSTER)	SE	MUN	
				CHESLEY	SW	MOE	
				NIAGARA-ON-LAKE (GC)	WC	MUN	
				BRUCE MINES	NE	MOE	
				BURKS FALLS	NE	MOE	
				EMO	NW	MOE	
				TEMAGAMI (N. GOWARD)	NE	MUN	EFF NH_3 ASSUMED < 10 mg/L
				RATTER & DUNNETT (WARREN)	NE	MOE	
				POWASSAN	NE	MOE	
				MARKDALE	SW	MOE	
				EAST GWILLIMBURY (HOLLAND)	C	MUN	
				BLACK R. MATHESON (VAL GA)	NE	MOE	
				ANDERDON (MCGREGOR)	SW	MOE	
				NORTH HIMSWORTH (CALL)	NE	MOE	EFF NH_3 ASSUMED < 10 mg/L
				WILMOT (NEW HAMBURG)	WC	MOE	
			MINOR (INFLUENT BOD 125-250 mg/L)	HARROW	SW	MOE	
				HAVELOCK	C	MOE	EFF NH_3 ASSUMED < 10 mg/L)
				LEEDS & LANSDOWNE	SE	MOE	
				ENNISKILLEN (OIL CITY)	SW	MOE	
				GLENCOE	SW	MOE	
				SHACKLETON & MACHIN (FAUQ)	NE	MOE	EFF NH_3 ASSUMED < 10mg/L
				CASIMIR J.A. (ST. CHARLES)	NE	MOE	
				ALFRED	SE	MOE	
				HEARST	NE	MOE	
				COSBY M.M. (NOELVILLE)	NE	MOE	
				STIRLING	SE	MOE	
				MOONBEAM	NE	MOE	EFF NH_3 ASSUMED <10 mg/L
				OMEMEE	C	MOE	
			MAJOR (INFLUENT BOD >250 mg/L)	MILVERTON	SW	MUN	
				GORE BAY	NE		
				BRANTFORD (CAINSVILLE)	WC	MUN	EFF NH_3 ASSUMED <10 mg/L

NOTE: THE PERCENT INDUSTRIAL CONTRIBUTION FOR LAGOONS WAS BASED ON INFLUENT BOD CONCENTRATIONS

LEVEL 2

STP's CATEGORIZED BY ANNUAL AMMONIA CONCENTRATIONS

TYPE OF PLANT	EFFLUENT AMMONIA CONC.	BOD REMOVAL (Percent)	INDUSTRIAL COMPONENT	PLANT NAME	MOE REGION	OPERATING AUTHORITY	COMMENTS
LAGOON	< 10 mg/L	< 80 %	DOMESTIC	LANCASTER	SE	MOE	
				MICHIPOCOTEN (WAWA)	NE	MOE	EFF NH_3 ASSUMED < 10 mg/L
				THESSALON	NE	MOE	
				ARMSTRONG	NE	MUN	EFF NH_3 ASSUMED < 10 mg/L
				TIMMINS (BOB'S LAKE)	NE	MUN	EFF NH_3 ASSUMED < 10 mg/L
				NEW LISKEARD	NE	MOE	
			MAJOR	NANTICOKE (STELCO IND P)	WC	MOE	
	> 10 mg/L	> 80%	DOMESTIC	BEETON	C	MOE	
			MAJOR	BROCK (SUNDERLAND)	C	MUN	
		< 80%	DOMESTIC	BLACK R MATHESON (RAMORE)	NE	MOE	

NOTE: THE PERCENT INDUSTRIAL CONTRIBUTION FOR LAGOONS WAS BASED ON INFLUENT BOD CONCENTRATIONS

LEVEL 2

STP's CATEGORIZED BY ANNUAL AMMONIA CONCENTRATIONS

TYPE OF PLANT	EFFLUENT AMMONIA CONC.	BOD REMOVAL (Percent)	INDUSTRIAL COMPONENT	PLANT NAME	MOE REGION	OPERATING AUTHORITY	COMMENTS
SECONDARY	< 10 mg/L	> 80 %	DOMESTIC	WESTMINSTER TWP	SW	MOE	
				WESTMINSTER (SOUTHLAND)	SW	MUN	EFF NH_3 ASSUMED < 10 mg/L
				THAMESVILLE	SW	MOE	
				EAST GWILLIMBURY (ALBERT)	C	MUN	EFF NH_3 ASSUMED < 10 mg/L
				ALVINSTON	SW	MOE	
				PLYMTON-WYOMING	SW	MOE	
				TERRACE BAY	NW	MUN	
				BARRY'S BAY	SE	MOE	
				VICTORIA HARBOUR	C	MOE	
				NORTH DUMFRIES (P.V. AYR)	WC	MOE	
				GRAND VALLEY	WC	MOE	
				HAGARTY & RICHARDS (KILL)	SE	MOE	
				PETROLIA	SW	MOE	
				BLYTH	SW	MOE	
				KAPUSKASING	NE	MOE	
				SHELBURNE	WC	MOE	
				BRANTFORD	WC	MOE	
				PARRY SOUND	NE	MOE	
				WASAGA BEACH	C	MOE	EFF NH_3 ASSUMED < 10 mg/L
				DURHAM	SW	MOE	
				KINGSTON	SE	MOE	
				MARMORA	SE	MOE	
				MILDMAY	SW	MOE	
				MERRICKVILLE	SE	MOE	
				DUNNVILLE	WC	MOE	
				MOORE (COURTRIGHT)	SW	MOE	EFF NH_3 ASSUMED < 10 mg/L
				COLDWATER	C	MOE	
				COBDEN	SE	MUN	
				HALDIMAND (CAYUGA)	WC	MOE	
				MARATHON	NW	MOE	
				DESERONTO	SE	MOE	
				S. DUMFRIES (ST. GEORGE)	WC	MOE	
				GERALDTON	NW	MOE	
				EAR FALLS	NW	MOE	
				LATCHFORD	NE	MOE	
				SMITH (WOODLAND ACRES)	C	MOE	
				IGNACE	NW	MOE	

LEVEL 2

STP's CATEGORIZED BY ANNUAL AMMONIA CONCENTRATIONS

TYPE OF PLANT	EFFLUENT AMMONIA CONC.	BOD REMOVAL (Percent)	INDUSTRIAL COMPONENT	PLANT NAME	MOE REGION	OPERATING AUTHORITY	COMMENTS
SECONDARY	< 10 mg/L	> 80 %	DOMESTIC (cont'd).	BATH	SE	MUN	
				BOBCAYGEON	C	MOE	
				LONGLAC	NW	MOE	
				ANSON HINDON MINDEN	C	MUN	
				SMOOTH ROCK FALLS	NE	MOE	
				HASTINGS	C	MOE	
				MOORE (CORUNNA)	SW	MOE	EFF NH_3 ASSUMED < 10 mg/L
				BLACK R MATHESON (MATH)	NE	MOE	
				FRANKFORD	SE	MOE	
				ATIKOKAN	NW	MOE	
				BLIND RIVER	NE	MOE	
				STURGEON FALLS	NE	MOE	
				RED LAKE	NW	MOE	
				MILLBROOK	C	MOE	
				PICKLE LAKE	NW	MOE	BOD EFF CONC ESTIMATED
				BALMERTOWN	NW	MOE	
				PITTSBURG (CANA)	SE	MOE	
				SIDNEY (BATAWA)	SE	MOE	
				HAILEYBURY (NEW)	NE	MOE	PLANT START UP NOVEMBER 1985
				PORT BURWELL	SW	MOE	
				ROMNEY (WHEATLY)	SW	MOE	
				HURON PARK	SW	MOE	
				ERNESTOWN (ODESSA)	SE	MOE	
				PICTON	SE	MUN	

LEVEL 2

STP's CATEGORIZED BY ANNUAL AMMONIA CONCENTRATIONS

TYPE OF PLANT	EFFLUENT AMMONIA CONC.	BOD REMOVAL (Percent)	INDUSTRIAL COMPONENT	PLANT NAME	MOE REGION	OPERATING AUTHORITY	COMMENTS
SECONDARY	< 10 mg/L	> 80 %	MINOR	NAKINA	NW	MOE	
				CHALK RIVER	SE	MOE	
				SOUTHAMPTON	SW	MOE	
				ELORA	WC	MUN	
				MOOSONEE (OLD)	NE	MOE	
				WICKSTEED (HORNEPAYNE)	NE	MOE	EFF HN_3 ASSUMED < 10 mg/L
				WELLESLEY	WC	MOE	
				NORWOOD	C	MOE	
				DELHI	WC	MOE	
				CALEDON	C	MUN	
				LEAMINGTON	SW	MUN	
				CORNWALL (LONG SAULT)	SE	MUN	
				BANCROFT	SE	MUN	
				FENELON FALLS	C	MOE	
				INGERSOLL(OLD)	SW	MOE	
				WELLINGTON	SE	MUN	
				PAISLEY	SW	MOE	
				HALDIMANO (HAGERSVILLE)	WC	MOE	
				TRENTON	SE	MOE	EFF NH_3 ASSUMED < 10 mg/L
				E. WILLIAMS (AILSA CRAIG)	SW	MOE	
				EGANVILLE	SE	MOE	
				SCHREIBER	NW	MOE	
				DUNDAS	WC	MUN	
				ORANGEVILLE	WC	MOE	
				BRUSSELS	SW	MOE	

LEVEL 2

STP's CATEGORIZED BY ANNUAL AMMONIA CONCENTRATIONS

TYPE OF PLANT	EFFLUENT AMMONIA CONC.	BOD REMOVAL (Percent)	INDUSTRIAL COMPONENT	PLANT NAME	MOE REGION	OPERATING AUTHORITY	COMMENTS
SECONDARY	< 10 mg/L	> 80 %	MAJOR	PARIS	WC	MOE	
				ALLISTON	C	MOE	
				WILMOT (BADEN)	WC	MOE	
				FERGUS	WC	MOE	
				BELLEVILLE	SE	MOE	
				BRADFORD	C	MOE	
				TILLSONBURG	SW	MOE	
				DRESDEN	SW	MOE	
				KENORA	NW	MUN	
				MEAFORD	SW	MOE	
				INGERSOLL (NEW)	SW	MOE	
				NORTH BAY	NE	MOE	
				WOOLWICH (ST.JACOBS)	WC	MOE	
				ST. MARY'S	SW	MOE	
				NAPANEE	SE	MUN	
				SIMCOE	WC	MOE	
				HAWKESBURY	SE	MOE	
				COLLINGWOOD	C	MUN	
		< 80 %	DOMESTIC	L'ORIGNAL	SE	MOE	
				HAILEYBURY (OLD)	NE	MOE	
				CAMPBELLFORD	C	MOE	
				IROQUOIS FALLS	NE	MOE	
				MOOSONEE (NORTH)	NE	MOE	
				PORT MCNICOLL	C	MOE	
				TUCKERSMITH (VAN ASTRA)	SW	MOE	
				LOBO (KILWORTH HEIGHTS)	SW	MOE	
			MINOR	KIRKLAND LAKE	NE	MOE	
				CARLETON PLACE	SE	MOE	
	> 10 mg/L	> 80 %	DOMESTIC	ESSA (ANGUS)	C	MOE	
				MAIDSTONE (BELLE RIVER)	SW	MOE	
			MINOR	WALLACEBURG	SW	MOE	
				WOOLWICH (ELMIRA)	WC	MOE	
		< 80 %	DOMESTIC	PALMERSTON	WC	MOE	
				NICKEL CENTRE (FALCONBR)	NE	MUN	EFF NH_3 ASSUMED > 10 mg/L

LEVEL 2

STP's CATEGORIZED BY ANNUAL AMMONIA CONCENTRATIONS

TYPE OF PLANT	EFFLUENT AMMONIA CONC.	BOD REMOVAL (Percent)	INDUSTRIAL COMPONENT	PLANT NAME	MOE REGION	OPERATING AUTHORITY	COMMENTS
PRIMARY	< 10 mg/L	< 80 %	DOMESTIC	OSNABRUCK	SE	MUN	INDUSTRIAL COMPONENT BASED ON PROF. JUDGEMENT
				MUSKOKA LAKES (BALA)	C	MUN	INDUSTRIAL COMPONENT BASED ON PROF. JUDGEMENT
				KINGSTON	SE	MUN	INDUSTRIAL COMPONENT BASED ON PROF. JUDGEMENT
				MANITOUWADGE	NW	MUN	INDUSTRIAL COMPONENT BASED ON PROF. JUDGEMENT
				FORT FRANCES	NW	MOE	INDUSTRIAL COMPONENT BASED ON PROF. JUDGEMENT
				MORRISBURG	SE	MUN	INDUSTRIAL COMPONENT BASED ON PROF. JUDGEMENT
			MINOR	OWEN SOUND	SW	MOE	
				PRESCOTT	SE	MOE	INDUSTRIAL COMPONENT BASED ON PROF. JUDGEMENT
			MAJOR	SMITHS FALLS	SE	MUN	
				CORNWALL	SE	MOE	
	> 10 mg/L	> 80%	DOMESTIC	NANTICOKE (PORT DOVER)	WC	MOE	
			MAJOR	RENFREW	SE	MUN	
		< 80 %	DOMESTIC	KIRKLAND LAKE (SWASTIKA)	NE	MUN	
				MCGARRY	NE	MUN	
				DELORO	SE	MUN	
				PETAWAWA	SE	MOE	
				DEEP RIVER	SE	MUN	
				PEMBROKE	SE	MUN	INDUSTRIAL COMPONENT BASED ON PROF. JUDGEMENT
				KEMPTVILLE	SE	MUN	INDUSTRIAL COMPONENT BASED ON PROF. JUDGEMENT
				POINT EDWARD	SE	MOE	INDUSTRIAL COMPONENT BASED ON PROF. JUDGEMENT
				NIPIGON	NW	MUN	INDUSTRIAL COMPONENT BASED ON PROF. JUDGEMENT
				CHAPLEAU	NE	MUN	NOW AERATED LAGOON, 4540 m^3/d CAP; INDUST. COMP. BASED ON PROF. JUDGEMENT
				IROQUOIS	SE	MUN	INDUSTRIAL COMPONENT BASED ON PROF. JUDGEMENT
			MINOR	THUNDER BAY	NW	MUN	
				ARNPRIOR	SE	MUN	INDUSTRIAL COMPONENT BASED ON PROF. JUDGEMENT
				SARNIA	SW	MUN	
			MAJOR	ESPANOLA	NE	MOE	
				SAULT STE. MARIE	NE	MOE	
				BROCKVILLE	SE	MUN	

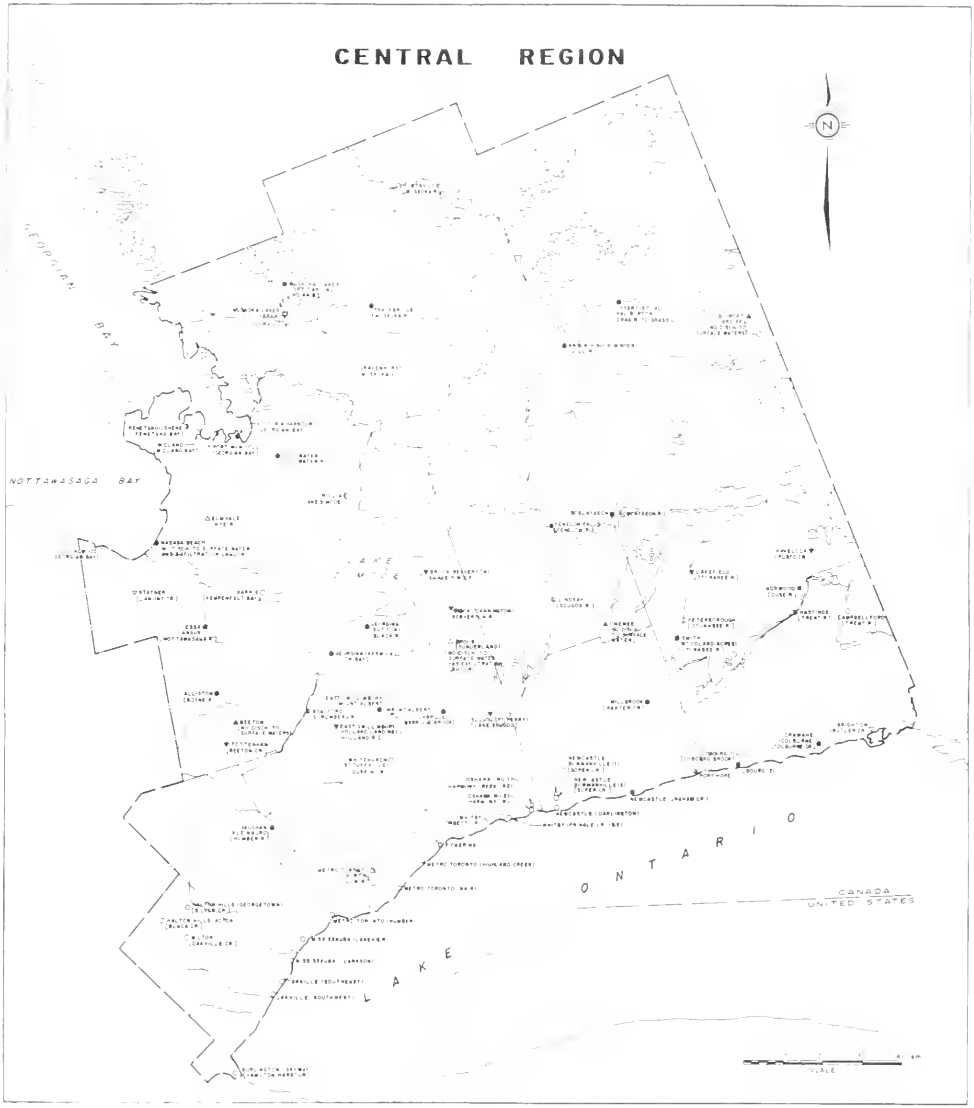
LEVEL 3

STP's WITH INSUFFICIENT DATA FOR PERFORMANCE EVALUATION

TYPE OF PLANT	EFFLUENT AMMONIA CONC.	BOD REMOVAL (Percent)	INDUSTRIAL COMPONENT	PLANT NAME	MOE REGION	OPERATING AUTHORITY	COMMENTS
LAGOON				NORFOLK (PORT ROWAN)	WC	MOE	BOD AND AMMONIA DATA NOT AVAILABLE
				ST. EDMUNDS	SW	MUN	EFF NH_3 OBT FROM OPERATOR
				TILBURY	SW	MUN	BOD AND AMMONIA DATA NOT AVAILABLE
				BICROFT	C	MUN	BOD AND AMMONIA DATA NOT AVAILABLE; NO DISCHARGE IN 1985
				OPASATIKA	NE	MUN	BOD AND AMMONIA DATA NOT AVAILABLE
				VAL RITA-HARTY (HARTY)	NE	MUN	BOD AND AMMONIA DATA NOT AVAILABLE
				VAL RITA-HARTY (VAL RITA)	NE	MOE	BOD AND AMMONIA DATA NOT AVAILABLE
				GOLDEN (COCHENOUR)	NW	MOE	BOD AND AMMONIA DATA NOT AVAILABLE; NO DISCHARGE IN 1985
				COULBOURN (RICHMOND)	SE	MOE	PHASED OUT 1986, EFF NH_3 ASSUM < 10 mg/L
				BEARDMORE	NW	MOE	BOD AND AMMONIA DATA NOT AVAILABLE
				TOTTENHAM	C	MUN	BOD AND AMMONIA DATA NOT AVAILABLE
				TERRACE BAY	NW	MUN	BOD AND AMMONIA DATA NOT AVAILABLE
				OIL SPRINGS	SW	MOE	BOD AND AMMONIA DATA NOT AVAILABLE
				IROQUOIS FALLS (PORQUIS)	NE	MUN	BOD AND AMMONIA DATA NOT AVAILABLE
PRIMARY				LARDER LAKE	NE	MUN	BOD AND AMMONIA DATA NOT AVAILABLE
				PORT COLBORNE (WEST)	WC	MUN	IRREGULAR USE, PRIMARY TREATMENT ONLY
				BLACK R MATHESON (MINES)	NE	MUN	BOD AND AMMONIA DATA NOT AVAILABLE
				BAIRD (MADSEN)	NE	MOE	BOD AND AMMONIA DATA NOT AVAILABLE
				BLACK R MATHESON (HOLTYRE)	NE	MUN	BOD AND AMMONIA DATA NOT AVAILABLE
				GOLDEN (BALNERTOWN)	NW	MUN	BOD AND AMMONIA DATA NOT AVAILABLE
				BRANTFORD (AIRPORT)	WC	MUN	BOD AND AMMONIA DATA NOT AVAILABLE
SECONDARY				CARAMAT	NW	MUN	BOD AND AMMONIA DATA NOT AVAILABLE
				NEWCASTLE (BOWMANVILLE 1)	C	MUN	OUT OF SERVICE
				NEWCASTLE (BOWMANVILLE 2)	C	MUN	OUT OF SERVICE

APPENDIX F

Maps of Ontario STPs



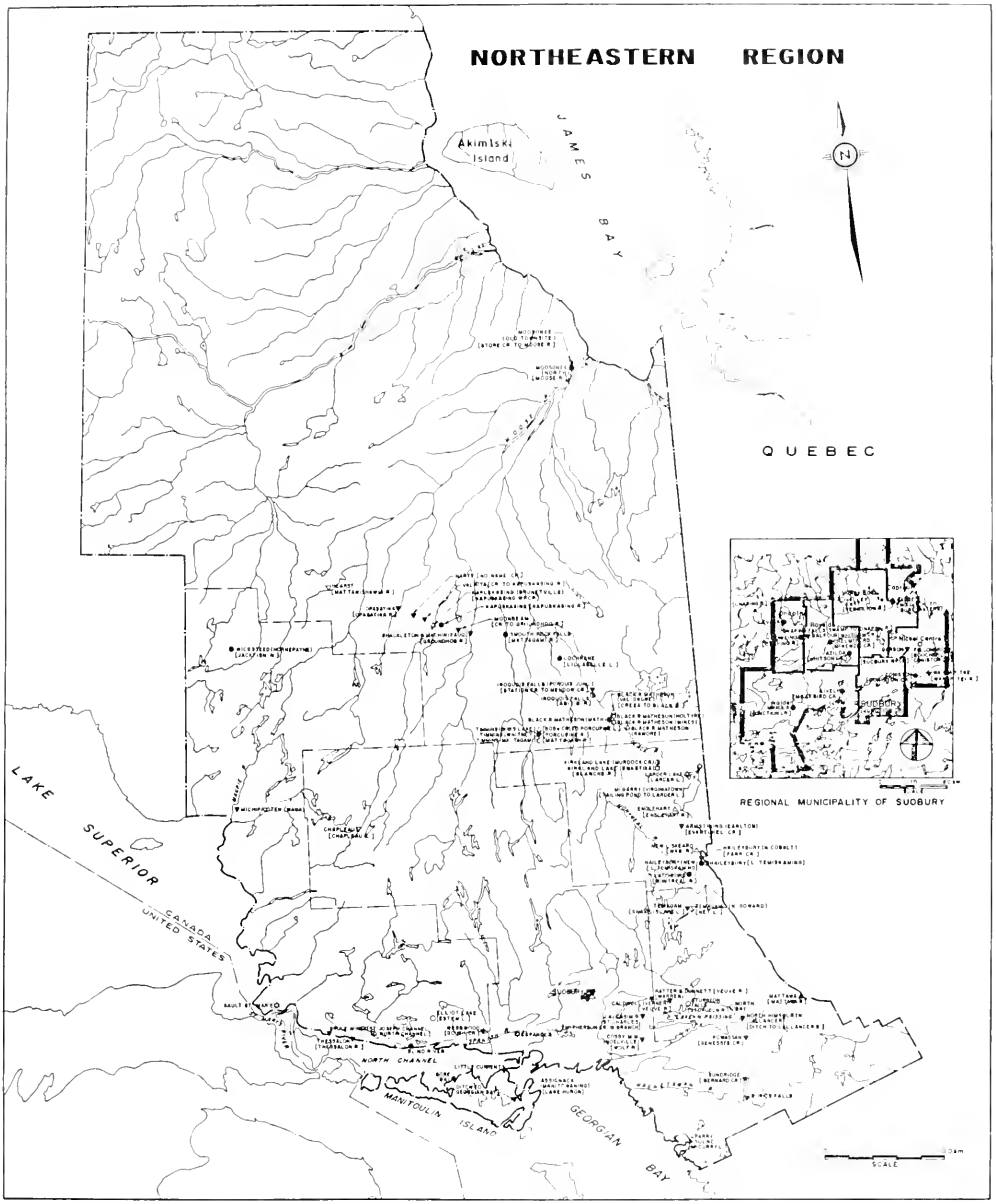
LEGEND

- ○ – CONVENTIONAL ACTIVATED SLUDGE (INCLUDES MODIFIED ACTIVATED SLUDGE)
- ◗ – CONTACT STABILIZATION
- ● – EXTENDED AERATION
- □ – TRICKLING FILTER (INCLUDES ROTATING BIOL. CONTACTORS)
- ◘ – HIGH RATE A.S.
- ◆ – OXIDATION DITCH
- ▽ – AERATED LAGOON (INCLUDES AERATED CELL & LAGOON)
- ▼ – SEASONAL LAGOON (INCLUDES ANNUAL LAGOON)
- △ – CONTINUOUS LAGOON
- ▲ – LAGOON WITH SPRAY IRRIGATION OR EXFILTRATION LAGOON
- ⬡ – PRIMARY TREATMENT (INCLUDES COMMUNAL SEPTIC TANKS)
- ( ) – DENOTES RECEIVING WATER FOR WPCP EFFLUENT

WATER POLLUTION CONTROL PLANTS IN ONTARIO MOE CENTRAL REGION

CANVIRO CONSULTANTS

bcnk best consultants limited



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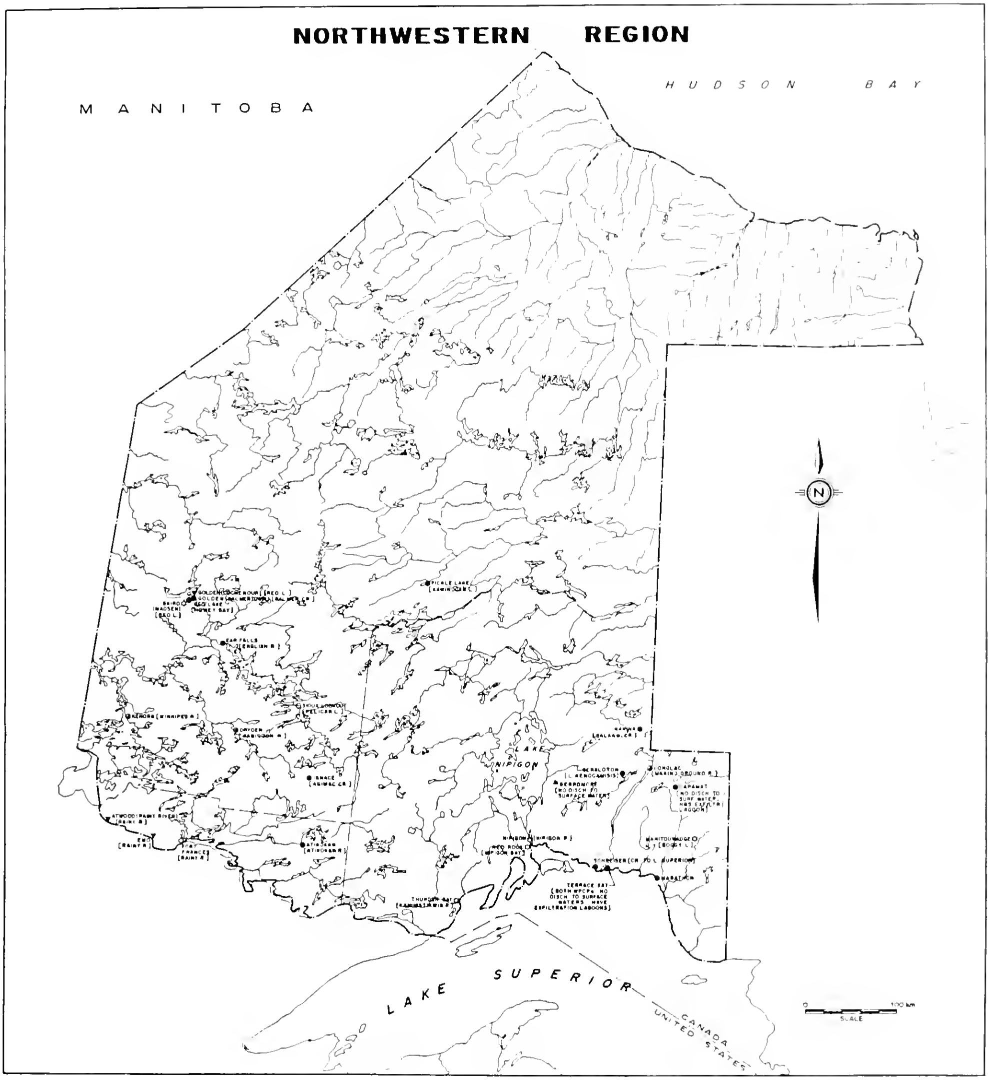
- [ ] – DENOTES RECEIVING WATER FOR WPCP EFFLUENT

WATER POLLUTION CONTROL PLANTS IN ONTARIO MOE NORTHEASTERN REGION

CANVIRO CONSULTANTS

beak consultants limited



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- ▽ – AERATED LAGOON (INCLUDES AERATED CELL + LAGOON)
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- △ – CONTINUOUS LAGOON
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- ⊙ – PRIMARY TREATMENT (INCLUDES COMMUNAL SEPTIC TANKS)
- [ ] – DENOTES RECEIVING WATER FOR WPCP EFFLUENT

WATER POLLUTION CONTROL PLANTS IN ONTARIO MOE NORTHWESTERN REGION

CANVIRO CONSULTANTS

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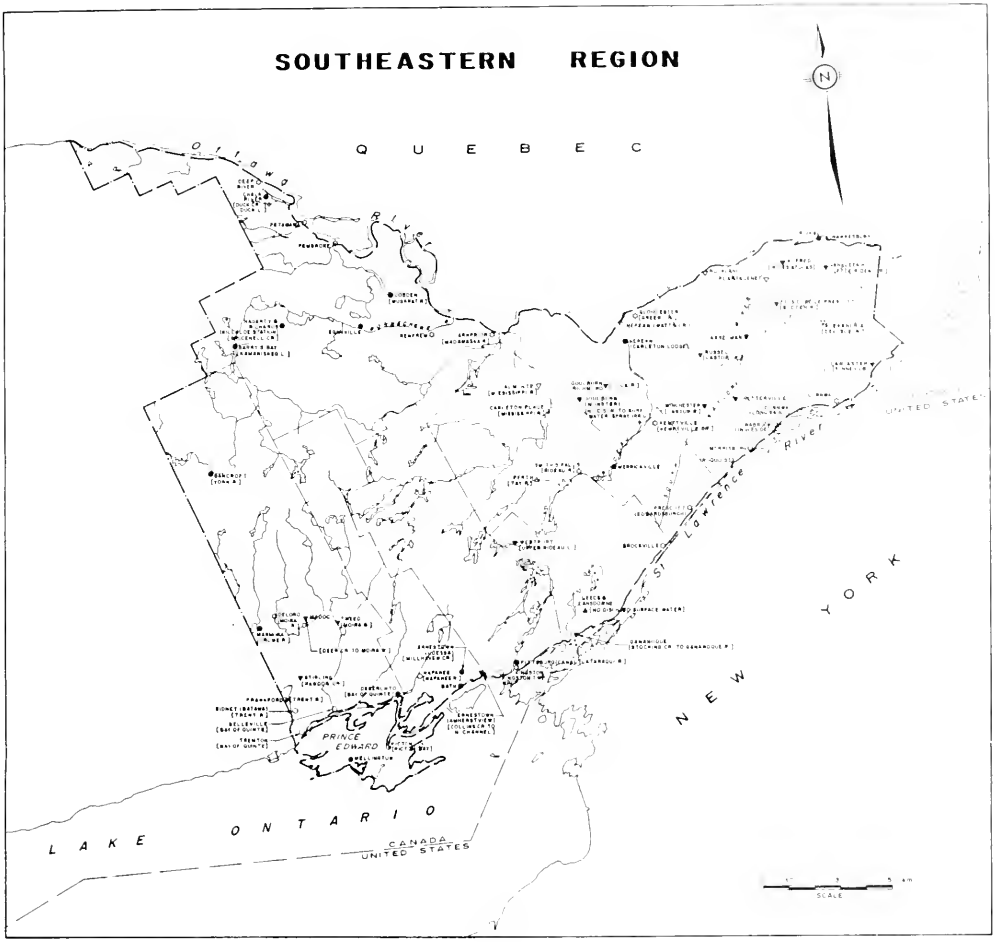

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- △ – CONTINUOUS LAGOON
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- ○ – PRIMARY TREATMENT (INCLUDES COMMUNAL SEPTIC TANKS)
- [ ] – DENOTES RECEIVING WATER FOR WPCP EFFLUENT

WATER POLLUTION CONTROL PLANTS IN ONTARIO MOE SOUTHEASTERN REGION

CANVIRO CONSULTANTS

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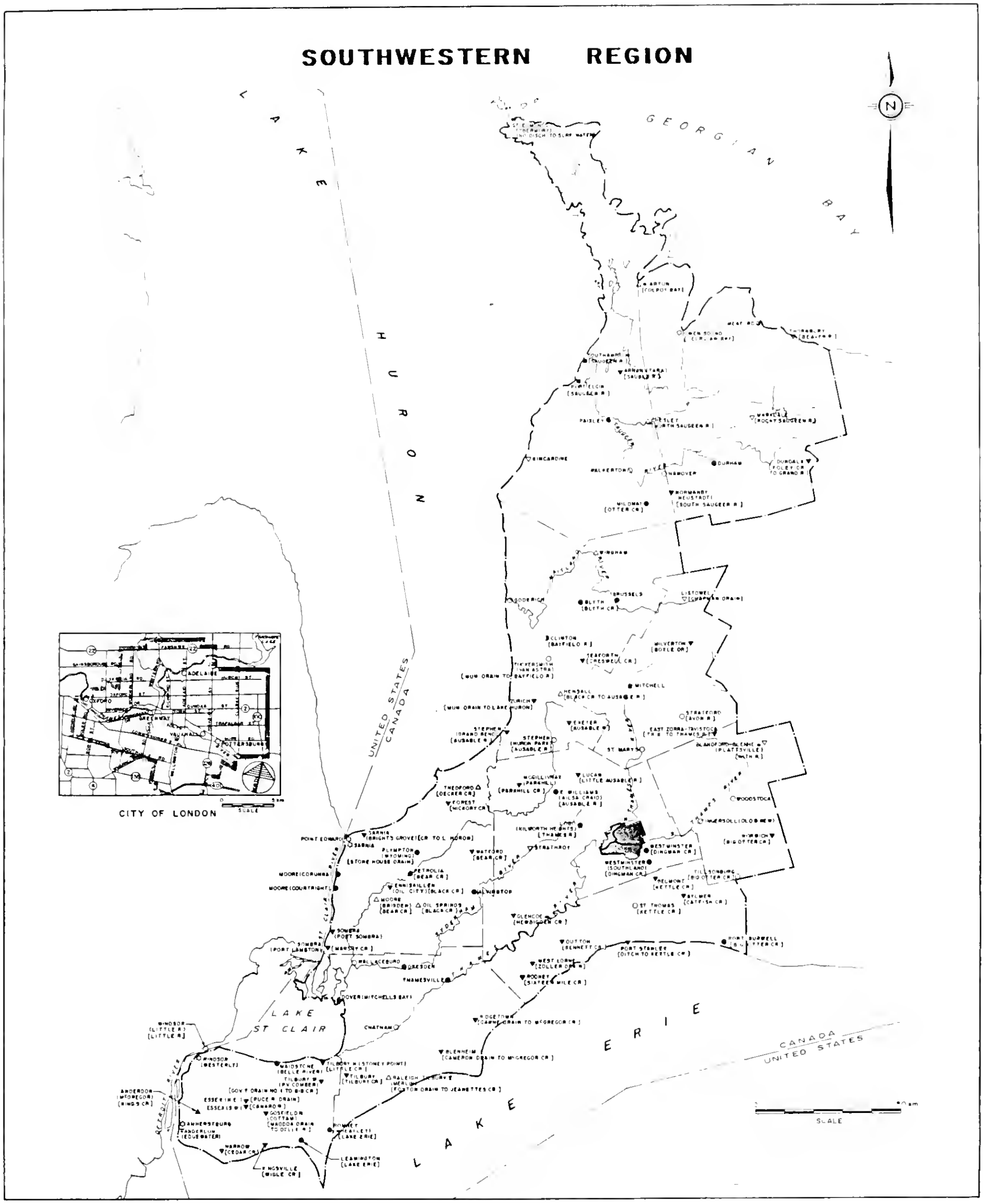

LEGEND

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- △ – CONTINUOUS LAGOON
- ▲ – LAGOON WITH SPRAY IRRIGATION OR EXFILTRATION LAGOON
- ○ – PRIMARY TREATMENT (INCLUDES COMMUNAL SEPTIC TANKS)
- [ ] – DENOTES RECEIVING WATER FOR WPCP EFFLUENT

WATER POLLUTION CONTROL PLANTS IN ONTARIO MOE SOUTHWESTERN REGION

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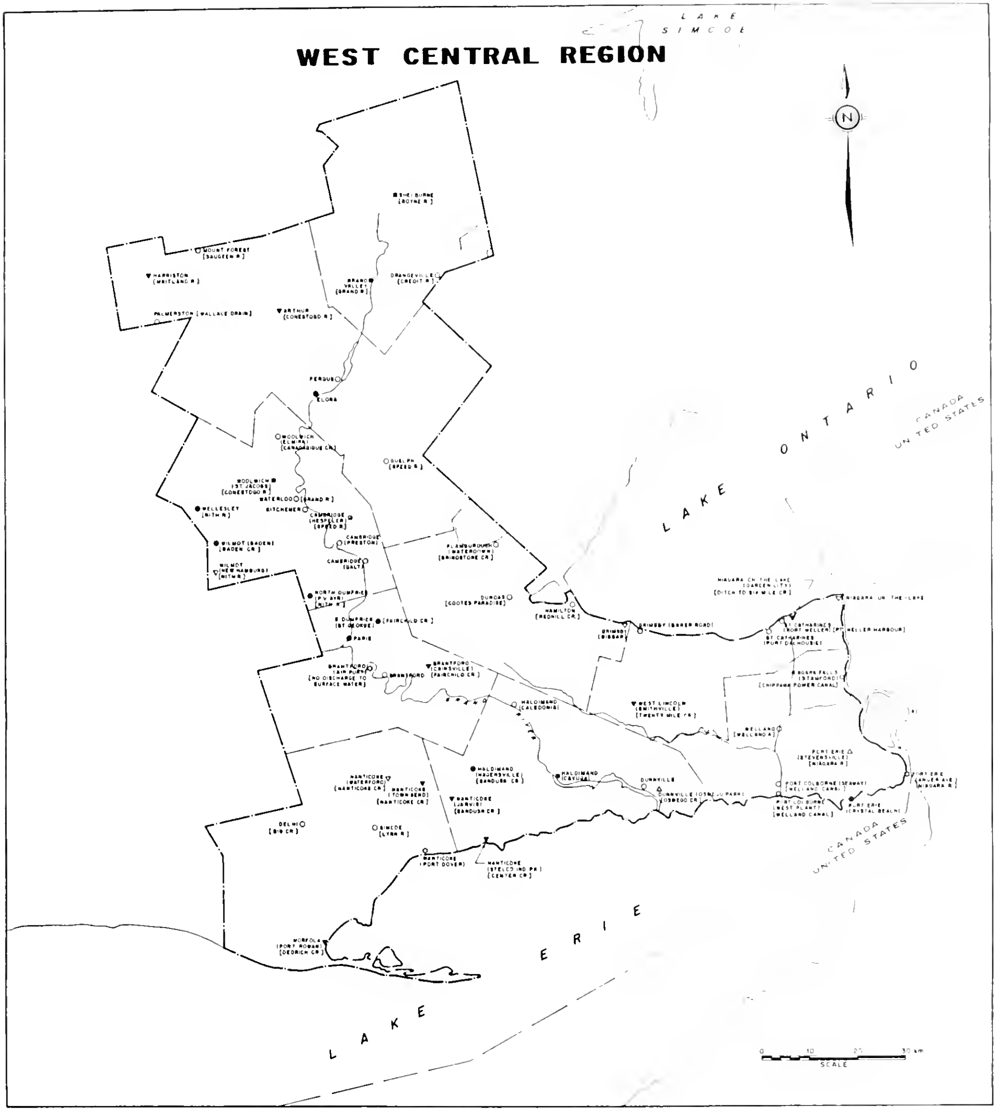

LEGEND

- ○ – CONVENTIONAL ACTIVATED SLUDGE (INCLUDES MODIFIED ACTIVATED SLUDGE)
- ◐ – CONTACT STABILIZATION
- ● – EXTENDED AERATION
- ◻ – TRICKLING FILTER (INCLUDES ROTATING BIOL CONTACTORS)
- ◼ – HIGH RATE A S
- ■ – OXIDATION DITCH
- ▽ – AERATED LAGOON (INCLUDES AERATED CELL + LAGOON)
- ▼ – SEASONAL LAGOON (INCLUDES ANNUAL LAGOON)
- △ – CONTINUOUS LAGOON
- ▲ – LAGOON WITH SPRAY IRRIGATION OR EXFILTRATION LAGOON
- ⊙ – PRIMARY TREATMENT (INCLUDES COMMUNAL SEPTIC TANKS)
- ( ) – DENOTES RECEIVING WATER FOR WPCP EFFLUENT

WATER POLLUTION CONTROL PLANTS IN ONTARIO MOE WEST CENTRAL REGION

CANVIRO CONSULTANTS

beak consultants limited